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THE VIRGINIA COPPER DEPOSITS.[1]

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INTRODUCTION.

The presence of copper ores in Virginia has been known since the foundation of the early settlements of the State. Many and costly attempts have been made to mine the ores, but thus far the only productive properties have been those of the Virgilina district. At the present time a number of properties are being developed in different parts of the State affording an opportunity for the study of conditions underground as well as at the surface.

The facts presented in this paper are the results of an examination of these deposits made by Mr. Weed for the U. S. Geological Survey, supplemented by observations of the geologist in charge of the Virginia Survey, preparatory to the issuing of a State report.[2] The microscopic study of the rocks and ores is the work of Professor Watson.

DISTRIBUTION OF THE COPPER ORES.

Geographical Distribution.—Copper ores are widely distributed throughout the State of Virginia, though there are but few producing mines at present. The ores are confined to the crystalline

[1] Published by permission of the Director of the U. S. Geological Survey. A further account of these observations will appear in Bull. 285 of the Survey, entitled Contributions to Economic Geology for 1905.

[2] This report, which will form Vol. IV of the Virginia Geological Survey, is about ready to go to press.

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rocks of the Piedmont and Blue Ridge areas, and to the red Triassic beds which form separate, disconnected, smaller areas over the Piedmont province.

The areas of these ores in the State, grouped geographically, are:

I. The Piedmont Region.
   (*a*) The Virgilina district, which includes Halifax county, Virginia; and Person and Granville counties, North Carolina.
   (*b*) The deposits on or near Southwest Mountain, Albemarle county; those of the Eastern Belt near Keysville, Charlotte county; and at Dillwyn, Buckingham county.

II. The Blue Ridge Region.
   Includes those deposits from near Front Royal southward, and embracing parts of Warren, Fauquier, Rappahannock, Madison, Page and Greene counties.

III. The Southwest Virginia Region.
   Includes the Gossan Leads of the Floyd-Carroll-Grayson counties plateau.

IV. The Triassic Area.
   Includes the deposits near Leesburg and Drakeville in Loudoun and Culpepper counties.

Geological Distribution.—The copper ores are confined to the crystalline rocks, either the schists or the massive igneous rocks of the Piedmont and Blue Ridge provinces, and to the red shale-sandstone series of the Triassic areas. In the Virgilina district the ores occur in quartz fissure veins which intersect or lie in an altered andesite (meta-andesite) of pre-Cambrian age.[1] The ores of the Blue Ridge region are disseminated through and segregated in basaltic flows of pre-Cambrian age, rocks designated by Keith as Catoctin schist.[2] The Gossan Leads of the Floyd-Carroll-Grayson counties plateau, in southwest Virginia, are mineralized faulted zones in schists of doubtful age, prob-

[1] Weed, Walter Harvey, *Trans. Amer. Inst. Mng. Engs.*, 1901, Vol. 30, p. 454. Watson, Thomas L., *Bull. Geol. Soc. Amer.*, 1902, Vol. 13, pp. 353–376.
[2] Keith, Arthur, 14th Ann. Rept. U. S. Geol. Survey, 1905, pp. 285–395.

ably pre-Cambrian in part. The rocks are in part altered sediments and in part igneous masses of basic and acid types, principally the former.

THE VIRGILINA DISTRICT.

Introductory Statement.—The Virgilina district, which derives its name from the town of Virgilina, located on the Virginia-Carolina boundary, is situated forty-seven miles east of Danville, on the Atlantic and Danville division of the Southern Railway.

The mines thus far developed all lie upon a low ridge, a flat-topped elevation of from one hundred to two hundred and fifty feet above the neighboring stream-valleys, which is from one-half to two miles or more in width. Prospecting is confined to an approximate north-south distance of eighteen miles along the ridge and to an average cross distance of from two to three miles. Although of no conspicuous height, the ridge forms a somewhat prominent feature in the landscape, and is traced northward in Virginia for a distance of ten miles. In North Carolina its southward extension is estimated by Hanna[1] to be about thirty miles, reaching nearly to Durham.

General Geology and Petrography.—The country-rock is schist. Natural outcrops are rare and seldom more than two or three feet high, forming sharp and narrow reefs which are persistent for short distances only. The microscope, as shown below, reveals the igneous origin of the rocks; but with few exceptions, their true igneous nature is not usually recognizable in the field. They are prevailingly finely laminated and schistose in structure, having the general characteristic features of a soft, green- to purple-colored schist, which on account of the large amount of chlorite present is designated greenstone schist. A number of sections showed the prevailing strike of the schistosity to be N. 10°–20° E., with an eastward dip of 70° to 80°.

The change in these rocks is clearly the result primarily of the processes of metamorphism, active while the rocks were deeply buried. At a subsequent time when the rocks were brought near the surface, they were further changed by weathering. The

[1] "Ores of North Carolina," Raleigh, 1888, p. 215.

mineral products resulting from such alteration are strongly in evidence. Diabase dikes of later geologic age cut the schist in several places. One of these dikes, twelve feet wide, is exposed in the Blue Wing mine at the hundred-foot level, where it is observed to cut across the schistosity of the rocks.

With but few exceptions thin sections of the rocks show a pronounced schistose structure under the microscope, the degree of schistosity varying from the thin banding of gneiss to the typical foliation of micaceous schist. The rocks vary in texture from dense aphanitic to medium fine-grained, with the porphyritic texture shown usually in the massive types. The original minerals are entirely altered to secondary ones in many of the thin sections, chiefly to chlorite and epidote; and it is rare, even in those of the most altered rocks, that some trace of the original outline of the feldspars is not shown, and more or less of the original rock texture preserved. Though true of the feldspar, the original bisilicate constituent is so completely altered in the slides studied, that no clue as to what the original mineral was is indicated. The texture varies from a partial micro-ophitic to microlitic in the non-porphyritic types, with the same variation and composition of groundmass in the porphyritic rocks denoted.

The minerals present are plagioclase, light green amphibole, chlorite, epidote, zoisite, calcite, iron oxide (partly magnetite), quartz and apatite. Of these only the feldspar, a part of the iron oxide (magnetite), and apatite are original. Both chlorite and epidote, intimately associated with more or less hornblende, are abundantly developed in most of the sections, sometimes one, sometimes the other, predominating; but the two are at all times intimately connected. Zoisite is in very subordinate amount and is closely intergrown with epidote, which forms an epidote-zoisite aggregate.

In many places over the district, the microscope shows the rock to be a volcanic clastic or tuff, the fragments of which are similar in all respects to the true igneous rocks.

The andesitic character of these rocks, in rather an advanced stage of alteration, is further made apparent in the following chemical analyses:

	I.	II.
SiO_2	64.12	62.32
TiO_2	trace	0.06
Al_2O_3	16.32	15.79
Fe_2O_3	7.72	3.57
FeO	1.38	4.61
MnO	0.64	0.35
CaO	3.49	3.65
MgO	0.33	2.53
Na_2O	6.22	4.51
K_2O	0.53	0.76
H_2O	0.34	1.89
	100.09	100.04

I. Dark purplish-gray, massive and slightly porphyritic rock, five-tenths of a mile south of Virgilina. Thomas L. Watson, analyst.

II. Dark massive greenstone, about one mile north of Virgilina. Thomas L. Watson, analyst.

The following conclusions seem to be warranted from a study of the rocks of this district:

1. The rocks have been greatly altered from pressure and chemical metamorphism, as indicated in the prevailing schistose structure, and the large development of the secondary minerals, chlorite, epidote and hornblende; and smaller amounts of others. The alteration has advanced sufficiently far in the more schistose phase to destroy, in most cases, the original structure and minerals of the rock.

2. From structural, petrographic and chemical evidence, it is shown that the rocks are derived from an original andesite. The altered andesite is intimately associated with the corresponding volcanic clastic. The name greenstone is applicable to the altered andesite of the district because of the abundant development of chlorite in it which imparts a somewhat distinctive green color.

3. The rocks are pre-Cambrian in age and represent an area of ancient volcanics similar to others described from numerous localities along the Atlantic Coast region from eastern Canada to Georgia and Alabama.

Mode of Occurrence of the Ores.—The workable ores comprise glance and bornite in quartz, and to a slight degree impregnations of the country-rock adjacent to the veins. At shallow

depths cuprite and malachite occur as alteration products of the original sulphides. A little native copper occurs in places. Chalcopyrite and pyrite are almost entirely absent. The ores are free from arsenic and antimony, but they carry at times very appreciable amounts of both gold and silver, particularly the latter.

The ore occurs in quartz veins. In some places it is disseminated as finely divided particles through the more massive portions of the rock, with the workable ore entirely confined to the

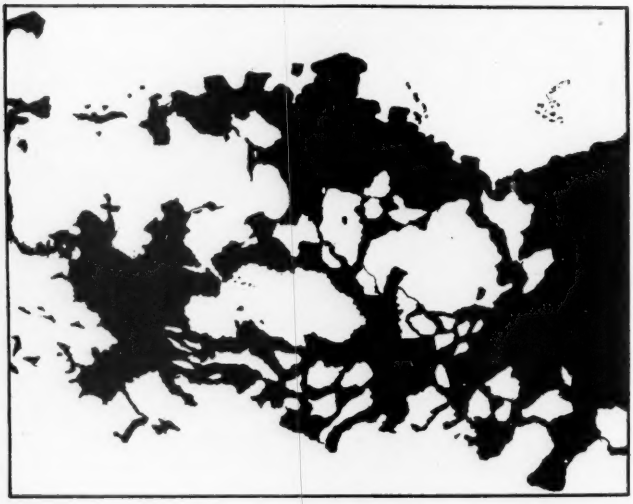

FIG. 19. Ore from the Virgilina District. Quartz with bornite. Black areas are bornite. White areas are quartz. Natural size.

quartz veins. The gangue consists principally of quartz with considerable calcite and epidote admixed locally. Fig. 19 shows the occurrence of the ore, bornite and glance in the quartz gangue.

The Veins.—The district has many veins, which in general are more or less parallel, having a course of N. 5°–10° E., and have overlapping ends. These veins cross the schistosity of the enclosing rock in part, and in part are parallel to it.

Mining developments show that copper occurs in almost all

of the veins in greater or less quantity. The veins are lenticular bodies of quartz, connected, and forming, in some cases, very uniform continuous outcroppings at the surface. They show, in general, a lenticular structure, and like the gold-veins of the Southern Appalachians they appear to be a succession of lenses connected by stringers of quartz. Fig. 20 shows the bulbous or lenticular form of the quartz. The largest veins show outcrops nearly continuous for a half mile to a mile or more, and the underground workings show a continuous body of quartz. Even the largest veins have a bulbous or lenticular form, and the vein pinches and widens, both horizontally and vertically. This is strongly marked in the smaller veins, and their lenses are frequently connected by a mere film or plate of quartz, which in certain horizontal cross-sections may be wanting, so that the vein appears to have given out.

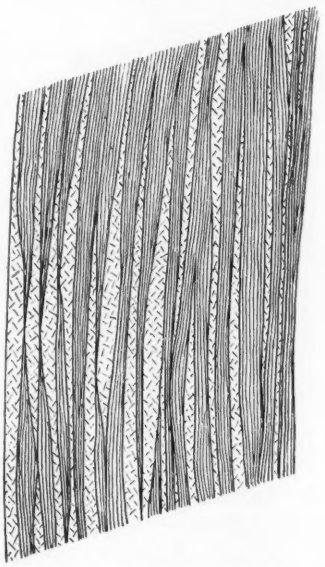

FIG. 20. Diagram illustrating the structure of veins formed by the tearing apart of schist included between fault-fissures or adjacent to fissures.

A marked banded structure is sometimes observed in the veins, commonly seen near the walls, though it sometimes prevails for the entire width of the vein. This banding is due to included plates of the altered schist, which are often so thin as to be mere films or dark streakings in the white gangue. Fig. 21, a section of the High Hill vein at shaft No. 4, Halifax county, Virginia, shows the banded structure. The schist-films are often marked by ore. In places, the banded structure is most marked where the gangue consists largely of calcite. In some cases it appears

as though a slight movement had torn apart the wall in a ragged way and quartz had filled in between the sheets of rock.

The veins show a generally uniform strike of N. 5°–10° E., though there are a few exceptions in which cross veins show a direction of as much as N. 20° E.

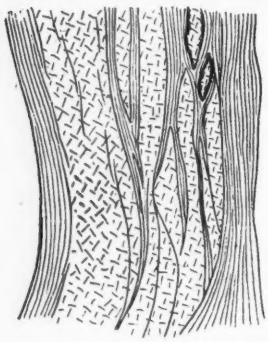

FIG. 21. High Hill vein at shaft No. 4. North face of 60-foot level. Vein 8 to 9 feet wide. Soft, fissile schist on the right.

Developments.—The district has been more or less prospected for the last fifty years, as shown by the pits and shafts extending eight miles north, and as far south, of the State line. The Gillis mine was opened in 1856,[1] but the district remained practically unexplored until 1897, though considerable money was spent in 1886–87, when the Blue Wing mine was opened and five hundred tons of ore were extracted. From 1898 to the present time active prospecting has been in progress and large sums of money have been spent in opening up the veins. A number of the large mines have sunk shafts to a depth of more than three hundred feet and have a total of several thousand feet of levels. The mines of the two largest companies are equipped with concentrating mills and both high-grade ores and concentrates have been shipped from them.

A majority of the mines have produced more or less ore, though in the summer of 1905 there was only one regularly producing mine in the district, the others being idle. This condition is not due, however, to a decrease in either the quantity or quality of the ore. Figures are not available upon which to base even an approximate estimate of the total amount of copper produced by the district, but that it has been reasonably large for an eastern area cannot be doubted.

[1] Geology of Midland Counties of North Carolina, Geol. Survey of N. C., 1856, p. 344.

THE BLUE RIDGE REGION.

General Statement.—The Blue Ridge copper region is located in the northern part of the State, and includes those deposits from near Front Royal southward, embracing parts of Warren, Fauquier, Rappahannock, Madison, Page and Greene counties.

The existence of copper ores in the Blue Ridge mountains has been known since the earliest settlement of the country. The native copper of the region probably furnished the Indians with the metal from which their ornaments and axes were made. A few attempts were made to extract the metal in colonial times, but not until 1854–56 were large sums of money expended in this region in attempts to work the ores. Operations were suspended at the beginning of the Civil War and the properties remained idle until within the past ten or twelve years, when attempts were again renewed to work the ore at many places over the region. In 1905 six companies and a few private individuals were engaged in development work.

With several exceptions, the work has all been of a superficial character. About six miles southeast of Luray, a property near Ida post office, has been developed by a shaft three hundred feet deep, but the usual depths attained in workings over the region will not exceed ninety feet, and very few of them even approximate this depth.

Geology and Petrography.—The Blue Ridge mountains of Virginia form a fairly continuous and well-defined ridge extending from Harper's Ferry southwestward to the State line. In places the ridge is quite narrow, as in the vicinity of Harper's Ferry, and in other places it spreads out into a number of connected ridges and spurs, as in the vicinity of Front Royal.

In the copper region, the Blue Ridge is made up of a central core of igneous rocks, mostly a dense basaltic rock flanked by syenite and other igneous types, frequently altered to schistose forms. Resting against these rocks at the base of the mountains and forming the valley region to the west is the folded sedimentary series, which according to Keith is Cambro-Silurian in age. The basal member of this series is a quartzite that forms

a nearly continuous ledge along the western flank of the mountains. The sedimentary series of rocks is, so far as known, not copper-bearing, for the copper ores of the region are confined to the igneous rocks of the basaltic type.

The basaltic rock is dense, heavy and dark-colored and varies from a basalt to a diabase, parts of which are usually altered and sometimes schistose. According to Keith the schistose character prevails in the Harper's Ferry region, and the rock is known as Catoctin schist. However, the schistose character of the rock further south in the copper region is much less well-defined. As a whole it appears more massive than schistose, though in places it is sheeted vertically from close-jointing along shear-zones.

Two varieties of the basic rocks are recognized near Harper's Ferry by Keith, a lower diabase sheet, and an upper basaltic sheet, both altered, with the upper one largely epidotized. The upper epidotized basalt sheet presents an amygdaloidal phase in places. The amygdules fillings are largely of quartz and epidote singly, or mixed, with epidote nuclei. Feldspar and calcite occasionally occur. In shape the amygdules are usually spheroidal, but they are frequently stretched and drawn out. They range in size from a small fraction of an inch up to half an inch and more, with a probable average of about a quarter of an inch. Copper and its compounds have nowhere been found in association with the amygdules.

Thin sections of the rock show variations from fine-grained basalt to, in the coarser varieties, diabase with pronounced ophitic texture. The principal minerals are augite, plagioclase, magnetite, some olivine, much secondary epidote and chlorite, and in many of the sections, leucoxene. The original constituents of the rock, augite and plagioclase, have been extensively altered, principally to chlorite and epidote, which usually impart a decided green color to the rock. Epidotization is a constant form of alteration.

A coarse-grained, usually massive, and dark-grayish-green syenite has been traced at irregular intervals along the west side of the mountains from Dickey's Hill south of Front Royal in Warren county, southward to High-top in Greene county. The

relations between the syenite and basalt observed on Stony Man mountain clearly indicate the later age of the first named rock. At most places the syenite is massive and topographically below the basalt. According to Phalen[1] the syenite in the Milam's Gap area is a hypersthene akerite, composed of the minerals, orthoclase, plagioclase, orthorhombic and monoclinic pyroxene, quartz, microline, iron ore, apatite and zircon, with the alteration products epidote, chlorite and sericite. Thin sections prepared from hand specimens gathered from a number of localities farther north, including Dickey's Hill, prove the rock to be similar to that found at Milam's Gap, namely, hypersthene akerite. In

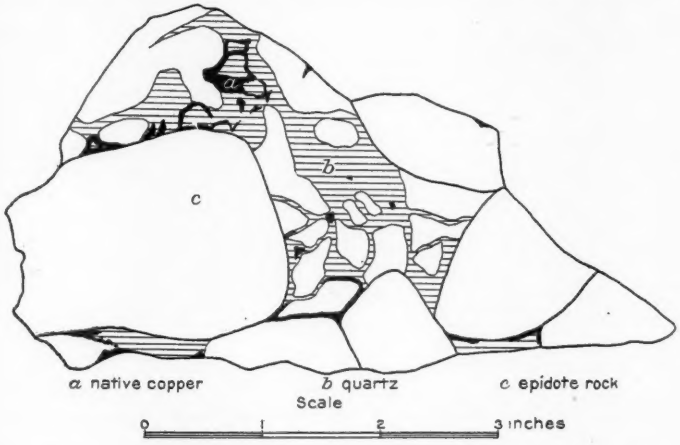

FIG. 22. Brecciated epidotized basalt with ore and quartz. Stony Man Peak.

the southern part of the region the copper deposits are formed (in part at least) near the contact of the basalt with the syenite.

The basic igneous rocks of the entire region have been generally much altered by dynamic metamorphism and secular decay, and in part form a greenish chlorite and epidote schist designated by Keith the Catoctin schist. According to this author the igneous rocks, including the basalt or Catoctin schist are Algonkian.

[1] Smithsonian Miscellaneous Collections, 1904, Vol. 45, p. 309.

The Character and Mode of Occurrence of the Ores.—The ores consist chiefly of cuprite and native copper, with small amounts of azurite and malachite, and still smaller amounts of the sulphides, bornite and chalcopyrite. The native copper often occurs as nucleal masses surrounded by cuprite. Bornite is in excess of chalcopyrite. The ore occurs along crevices and joint-planes, in small irregular shaped lenses of quartz, and as disseminated grains through the more epidotized portions of the basalt. It occurs only where the rocks are fractured and epidotized as shown in Fig. 22. When ore-bearing the rocks are yellowish-green epidotic and, in part, chloritic, altered by hydro-metamorphism. Fig. 23 shows a partial basalt shell filled with epidote, and the epidote rimmed by bornite next to the basalt.

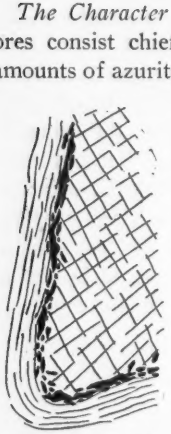

FIG. 23. Part of basalt shell filled with epidote and rimmed by bornite "Empire Vein," Warren County, Va.

Rarely are the quartz veinlets over a foot or two long and four inches wide, and they may be regarded as segregation veins filling strain cracks in the rock. Figs. 24 and 25 show the occurrence of native copper in quartz and in asbestiform serpentine.

At many of the localities the ores do not extend more than fifty feet below the surface, usually less. From their occurrence in shear-zones in the rock; from the confinement of the ore mainly to secondary epidote and quartz veinlets; and from the character of the ore itself; it is concluded that this type of deposit is formed by a local concentration of material leached out of locally copper-rich portions of the igneous rock, in which the copper was probably present as minute particles of cupriferous pyrite or chalcopyrite. It is, therefore, a product of superficial alteration, the shear-zone affording a place for the gathering of the solutions and the deposition of material. The ores seldom occur in actually continuous masses, but can sometimes be traced for miles by the copper-bearing débris.

In general no distinct veins occur, and as a rule the ore is found in quantity only in the upper thirty feet of the rock, occurring either in joints or impregnating the rock on either side. Small and irregular patches of quartz and cuprite and native copper also occur in the rock, often without any recognized connec-

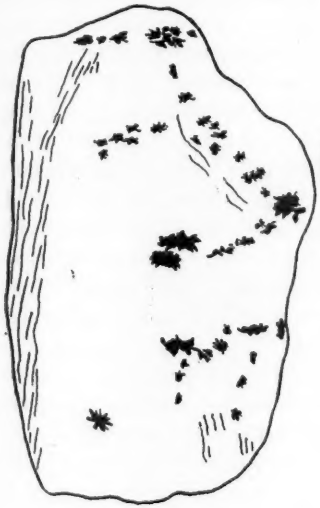

FIG. 24. Quartz with a little calcite and native copper. Black areas copper. Lined area schistose basalt. Fletcher, Greene County, Virginia.

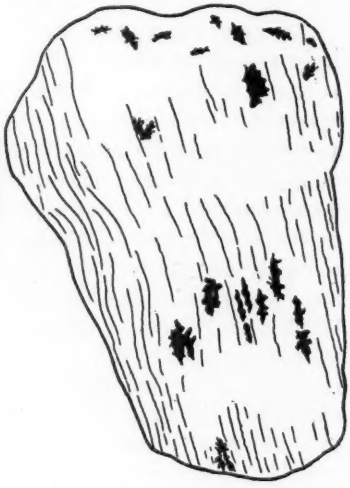

FIG. 25. Asbestiform serpentine with native copper. Black areas copper. Seven miles southeast of Luray, Page County, Virginia.

tion with intersecting fissures. The little gash-veins of quartz, and the horizontal strain cracks filled by serpentine and ore, point to a recent origin due to surface waters; in fact, the ores are confined to the epidote rock and do not occur below the general zone of such epidote alteration, except where crushing and fissuring have carried this action exceptionally far down.

Genesis of the Copper.—It is well known[1] that diabase rocks

[1] Copper deposits of New Jersey. Ann. Rep. of State Geologist of New Jersey, p. 136.

contain copper. According to Weed the Orange Mountain rock of New Jersey contains about one-fortieth of one per cent. The basaltic rock of the Blue Ridge region is undoubtedly the source of the copper in that area. The localization of the ores is due in part to original differences in composition, and in part to conditions of fracturing and water circulation, the result of local conditions.

The areas of basalt in the Blue Ridge are noticeable for the large amount of epidote which occurs in bands in the rock and is strewn in abundance over the surface of the ground. Mining operations in the vicinity of Front Royal have brought out the fact that the epidotization is primarily a surface phenomenon, though it may extend downward along shear-zones to a considerable depth. The epidotized rock, which is readily recognizable by its color from the underlying blue, less altered, rock, often contains nests and veinlets of calcite and of serpentine. There seems good reason to believe that some of the irregular, isolated bunches of ore and the little veinlets filled by serpentine are due to tension resulting from the expansion, amounting to, roughly speaking, about one third the volume. According to recent studies by Phalen epidote is also formed by inter-reaction between pyroxene and feldspar in the massive rock of the deep levels.[1]

Epidotization appears to be a recent phenomenon due mainly to surface waters; it is closely connected with the appearance of native copper and copper oxide, more rarely of bornite and chalcopyrite, as films and minute nodules scattered through the rock.

At all but one of the localities where copper ores are found, the deep workings show bunches and stringers of calcite and serpentine, but no copper, though various transitions to the surface ores may be observed with gradual replacement of calcite by copper, as a result of the action of infiltrating waters.

CONCLUSIONS REGARDING THE GENESIS OF THE BLUE RIDGE ORES.

The copper-bearing rock of the Blue Ridge region basalt, has undergone regional alteration, with local epidotization and a

[1] Bull. 285, U. S. Geological Survey.

further alteration resulting in the production of quartz, and to a less extent calcite, feldspar and asbestiform serpentine, with associated native copper, malachite, azurite, cuprite, some bornite and scant chalcopyrite, and possibly chalcocite, nowhere developed in commercial quantity. The ores represent local segregations, occurring in altered zones or patches, and in some places developed perhaps on a greater scale in zones of the softer and more altered rock occurring near a syenite contact. Here such zones have formed along a prominent system of close vertical joints. Where the joints are locally concentrated we have a natural path for downward moving superficial waters, which have produced the ore deposits, and it is along such paths that we find the greatest alteration. When it is remembered that the basalt has undergone local alteration perhaps throughout its mass, beyond the regional alteration mentioned, and that the copper has not been introduced by the syenite, but exists disseminated throughout the basalt, it will be understood why the ore does not appear to be restricted in its distribution to the soft zones near the syenite contact.

The copper has been derived from the basalt, where it existed as thinly disseminated chalcocite, and perhaps in the form of other sulphides and chalcopyrite. These minerals were acted on by percolating waters and were dissolved, carried and redeposited with vein materials along the joint-planes of the rock, forming small veins and patches or local segregations. The richest ore is found near the surface where the solvent power of the atmospheric waters is the strongest, and it apparently steadily diminishes in depth—a condition which seems to obtain at the mines of the Virginia Consolidated Copper Company near Luray. Here the alteration has extended to a depth of two hundred and eighty feet, but the richest ore was found thirty feet below the surface.

THE SOUTHWEST VIRGINIA REGION (GOSSAN LEAD).

General Statement.—The most noted copper region of Virginia is in the southwestern portion of the State, in a belt of crystalline rocks passing through Floyd, Carroll and Grayson

counties. The region is a part of the eroded Blue Ridge upland, marked by well rounded summits and deeply trenched streams, and is referred to as the Floyd-Carroll-Grayson plateau.

The region was actively prospected in the early fifties, and the rich secondary copper ores found beneath the gossan were boxed and shipped to Baltimore. During 1854–5 there were eight producing mines on the Gossan Lead; the aggregate amount of ore shipped for the six months from January, 1855, to July, 1855, being 1,454,363 pounds. The ore averaged about 25 per cent. copper and at that time the metal was worth twenty-six cents per pound.

GENERAL GEOLOGY AND PETROGRAPHY.

The Gossan Lead lies in the crystalline schists, and its strike conforms very closely to that of the enclosing rocks. A careful examination shows the vein to be traceable for a distance of eighteen miles. From one end to the other there are old pits whose dump-heaps show the typical gossan ore, and as several of the old mine workings could be continuously followed underground for miles, running at a depth of twenty to sixty feet below the surface, there seems little doubt that it is one of the greatest veins in the Appalachians.

The immediate wall-rock of the lead consists of highly lustrous sericite schist. To the southeast on the hanging-wall side of the vein the rocks are, throughout most of the course of the vein, ordinary mica-schists, which are cut by more or less altered fine- and coarse-grained diorite. The foot-wall rocks appear to belong to a different series, and are in part at least similar in lithologic character and position to the Ocoee rocks of the Southern Appalachians. No detailed section was made of the series, but it is certain that between the quartzite of presumable Cambrian age, which flanks the mountain region and defines it from the Shenandoah Valley, there is a belt of hornblende syenite, much altered from mashing and squeezing and in places resembling greenstone. Occasionally this belt extends upward and across the Ocoee (?) series, and is found near the Gossan

Lead, but nowhere were these rocks observed on the hanging-wall side of the vein. These facts and the structure of the vein itself prove faulting, and as the dip of the vein is from 45° to 60° there is little reason to doubt that the faulting is of the overthrust type, which predominates in this portion of the Appalachian region.

Microscopical Characters of the Rocks.—The main country-rock is mica schist of a pronounced and thinly foliated type; more or less feldspathic and containing a sprinkle of garnet. Feldspar is variable in amount, nearly failing in several slides. Garnet is not noticeable in the hand specimens but is present in every thin section studied.

Thin sections of the immediate wall-rock of the vein show a typical sericite schist, composed principally of sericite with a little quartz and usually considerable iron oxide. In places thin sections of the wall-rock indicate a typical mica schist containing some feldspar and garnet, and entirely similar to the country-rock in general. A thin section cut from a drill-core taken from a depth of five hundred feet below the surface at the Cranberry mine, showed a mica schist with the biotite folia noticeably bent and curved, and the quartz and feldspar marked by wavy extinction. Field and microscopic study of the mica schist clearly indicate that it is a metamorphosed sediment.

Eruptives, more or less altered, are frequent over the area. These are hornblendic rocks which, with the single exception noted below, conform to the diorite type. Thin sections cut from the rocks gathered along the vein from Little Reed Island Creek to Chestnut Creek show remarkable uniformity. Brown hornblende and its "reedy" form is the predominant mineral, with feldspar, quartz, epidote and iron oxide. Extending northward from the northwest edge of Sylvatus is an area of hornblende syenite, the exposures of which show pronounced crushing and shearing from pressure-metamorphism. Pressure effects are plainly marked in the slides in the broken and shattered feldspars, especially plagioclase, and undulatory extinction.

GENERAL CHARACTER OF THE VEIN.

The vein consists essentially of pyrrhotite with disseminated particles and stringers of chalcopyrite. It is not in every place a solid mass of pyrrhotite from wall to wall, but rather a series of layers, partly of pure pyrrhotite admixed with more or less micaceous material, an altered form of the country-rock. The primary ore is exposed at the openings of the Pulaski Mining Company at Chestnut Creek at the southwest end of the lead. Projecting masses or intercalations of the schists occur in the vein and, in places, where the fresh material is observable, a considerable proportion of the vein consists of coarse biotite schist impregnated with chalcopyrite and interleaved masses of pyrrhotite. Fig. 26 shows the interleaving of pyrrhotite with talc at the Pulaski Mining Company's opening on Chestnut Creek. Quartz lenses occur on the hanging-wall of the vein.

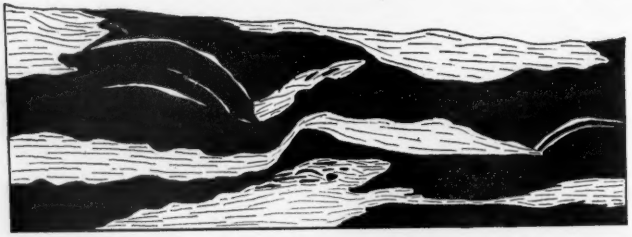

FIG. 26. Pyrrhotite interleaved with talc. Black is pyrrhotite. Lined areas are talc. Chestnut Yard, Carroll County, Virginia. Two-thirds natural size.

The vein varies in width from twenty-two feet to perhaps one hundred feet. A diamond drill hole was put down to a depth of five hundred and twenty-four feet on the vein at the Betty Baker mine, proving the deposit to a depth of seven hundred and thirty-four feet below the outcrop. Other borings proved the width of the vein at Betty Baker to be thirty-five feet. The strike of the vein varies in accordance with that of the country-rock; at Betty Baker it is N. 35° E., and it shows various deviations from this when traced southward, reaching as much as N. 60° E. in places. It has not only suffered from strike faulting, but shows sharp folding or change of strike southwest of the

Cranberry mine; and at the Betty Baker mine a horizontal displacement of sixty-two feet was measured close to the point where the wagon road crosses the ledge. The dip varies somewhat but averages about 45°. Marked discordance in the dip of the vein and that of the enclosing schists is observed in places.

In places the vein filling comprises rock-fragments of varying character, cemented by the sulphides, principally pyrrhotite. These fragments are often well-rounded, sometimes sub-angular, and include rock types not seen on the surface, either at the vein or nearby. Fig. 27 is a sketch of a hand specimen of the ore containing quartz fragments at the Betty Baker mine. The same brecciated structure was observed in the ores of each locality visited, but nowhere is it so prominent as in the Betty Baker mine. The evidence seems to indicate the origin of the fragments as friction breccia. The occurrence of rounded quartz balls indicates that the vein was formed after the segregation of the quartz veinlets. Since the vein filling is solid and massive, showing neither schistosity nor sheeting, though the enclosing rocks are thoroughly altered by regional metamorphism, it is believed the evidence confirms the conclusions reached from the study of the rocks and of the included fragments, namely, that the vein is much later in period of formation than the enclosing rocks, and was formed after the period of metamorphism which disguised the original character of the rocks.

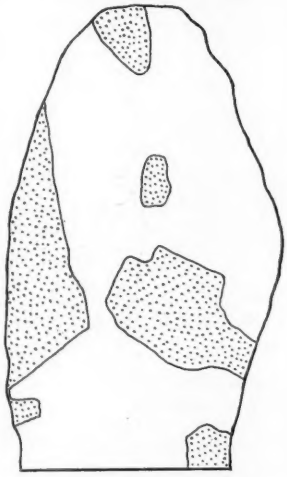

FIG. 27. Pyrrhotite with inclusions of quartz fragments. Betty Baker mine, Carroll County, Virginia.

Petrography of the Ores and Associated Minerals.—The unaltered ore is pyrrhotite with disseminated chalcopyrite. These

are massive and show no evidence of banding, either under the microscope or in the hand specimens. The proportion of chalcopyrite to pyrrhotite is very small and the two are inextricably mingled.

As regards species, the associated minerals are few in number. In the slides studied calcite and muscovite with biotite comprise the principal minerals. An occasional garnet and a little feldspar and quartz occur in several slides. In addition to these, hornblende is a principal mineral in thin sections of the ore collected on Chestnut Creek, and talc is abundant in hand specimens of the ore collected from this locality, as shown in Figs. 26 and 28.

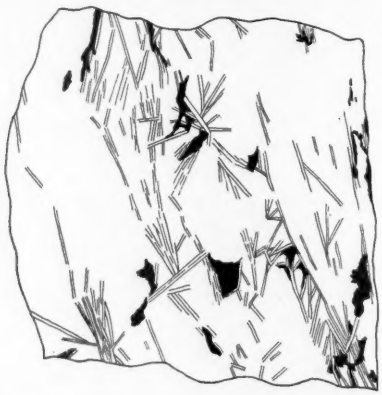

FIG. 28. Pyrrhotite with columnar hornblende and chalcopyrite. White is pyrrhotite. Black is chalcopyrite. Parallel lines are hornblende. Chestnut Yard, Carroll County, Virginia.

In every slide examined the ores are plainly shown to be subsequent in period of formation to that of the associated minerals, and in places the process was largely that of replacement. The microscopic evidence for this may be summed up as follows: (1) Almost without exception grains and areas of single and mixed calcite and mica and several of the other minerals are completely enclosed by and distributed through the substance of the

sulphides; (2) fractures which are so marked in the garnet, when this mineral is present, are penetrated and partially filled by the sulphides; (3) the sulphides have followed and formed along the sutures of the grains of calcite and the shreds of mica, replacing to some extent their substance; (4) the sulphides are frequently interleaved with the mica; (5) the sulphides have formed along the cleavage cracks in the mica and calcite, and in the latter the cleavage angles are sharply defined in the peripheral portions of the sulphides; and (6) perfect rimming at times of the individual minerals by the ores and replacement indicated in each case.

From all obtainable evidence, it seems reasonably certain that the two sulphides, pyrrhotite and chalcopyrite, were introduced and deposited about the same time. In some specimens the manner of distribution of the chalcopyrite through the pyrrhotite, chiefly in irregular stringer fashion, leaves but little doubt that in such cases the chalcopyrite was formed after the pyrrhotite. In other specimens of massive pyrrhotite containing very small pieces or "eyes" of the rock, chalcopyrite is invariably associated with the small pieces of rock, after the manner of reaction rims in igneous rocks, suggesting a possible chemical reaction between the rock substance and the copper-iron sulphide solution.

Specimens of the ore gathered from the Betty Baker mine usually show more than the average amount of chalcopyrite from the other mines on the lead. In some of these the distribution of the chalcopyrite through the pyrrhotite is in the form of small massive, roundish and squarish pieces, suggesting that the chalcopyrite was formed in advance of the pyrrhotite.

Secondary Enrichment of the Ores.—Secondary enrichment, which proved so marked a feature of these mines and led to their working in the early fifties, may be observed in several of the recent workings. The gossan has a depth of from twenty to sixty feet, averaging a greater depth on the hilltops than in the ravines. Beneath the gossan there is usually from one to six feet of the secondary copper ores comprising near the top more or less carbonate and oxide, and very rarely a little native copper, and further down on top of the unaltered sulphides, from a few inches up to six or even eight feet of soft black ore, the so-called

"smut-ore" of the miners, consisting mainly of secondary chalcocite.

FUTURE OF THE GOSSAN LEAD.

So far as mining operations extend, the amount of chalcopyrite becomes scanty in depth. In recent attempts to mine the ore for copper the percentage of copper in the output of the mines was reckoned at 0.6 to 1 per cent., which will not permit the working of the vein for copper alone. The future value of the "Gossan Lead" apparently lies mainly in its unworked iron ores and the utilization of the magnetic pyrite for acid making. There is a reasonable probability, however, that ore-shoots carrying 3 to 6 per cent. copper may be found when the vein is developed. The fact that all parts of the "Gossan Lead" are cupriferous, as shown by the early black copper workings, as well as all the primary sulphide ores opened up, make it not at all improbable that in its known extent of eighteen miles there are places where it is locally above the average in copper content. Moreover, the development of the primary sulphide ore has been confined to only three places, namely, Betty Baker, Cranberry and Chestnut Ridge.

THE TRIASSIC AREA.

The red sandstones and shales of the Triassic formation contain sparsely disseminated copper compounds in places, but too generally diffused to be profitably worked. Attempts were made in the early part of the last century to mine the ores over parts of Loudoun, Culpepper and Orange counties. In places the area of mineralization is extensive and considerable work has been done. No veins have been found and no well-defined horizon exists. The ores occur for the most part as films or thin coatings of malachite on the joint surfaces, and as disseminated grains of the sulphide and phosphate of copper through the rock. Rich specimens of copper glance and copper phosphate are sometimes obtained but they are of rare occurrence.

SEDI-GENETIC AND IGNEO-GENETIC ORES.

H. Foster Bain.

That ores represent concentrations of metals or minerals widely disseminated in minute quantities is now generally recognized. That the concentration has been in the main effected by aqueous solutions is scarcely less generally agreed. There is, however, considerable disagreement as to the sources of the solutions and the processes through which the concentration has been brought about. That these processes are numerous and varied seems well established, and it is too late to attempt to refer all ore deposits to any one process. There is so much doubt as to the relative importance of different processes in the production of individual deposits that it is exceedingly hazardous to attempt any estimate of the relative general importance of processes. Such attempts as have hitherto been made have been of what might be called qualitative order only. They have been personal judgments based upon as careful a sifting of individual impressions as possible, or deductions from general theory. Despite the great doubt attaching to many deposits and the general incompleteness of the data, it seems worth while to attempt a quantitative estimate of the relative importance in ore production of certain major groups of processes. It is hoped that the conclusions, while tentative, may be at least of temporary value.

Such a test as the one proposed, in order to be of value, must be applied to a region in which there is a large and representative variety of ore deposits; to one in which many at least of the deposits have been carefully studied; to one in which statistics of production are fairly accurate and complete for a long series of years. The latter condition is especially important since it is manifestly impossible to take into account the unmeasured ore remaining in the ground. The statistics of production and value for a single year or even a decade are so influenced

by extraneous factors that averages must be based on a large number of figures in order to neutralize temporary conditions. These various conditions seem fairly well met in the United States.

Geographically the area chosen is a sufficiently large and representative portion. Geologically it is not less so, since all the great systems and all varieties of igneous rocks have fair development. The geologic history has been varied, and has called into play, in what may be called the normal proportion of activity, all the great geologic processes which result in the concentration of ores. In variety of ores this country is notable as it also is in the number of occurrences of the ores of each metal.

Under inspection, it seems probable that the ores of the common metals occur here in about the same relative proportion as in the world at large. The region is not notably rich nor notably poor in any one in comparison with the others. If, then, we could measure and value all the ores mined and remaining in this territory and correctly apportion them according to genesis, we might fairly arrange the processes in sequence according to their importance. Since this is manifestly impossible, it remains to inquire whether the total production of certain of the ores might not be sufficiently representative. Ores, being by definition dependent upon commercial conditions, production must be in turn dependent upon trade conditions. It seems safe to assume that in the irregular industrial career of this country these conditions have varied often enough to call out the different ores somewhat in proportion to their abundance in nature. While the industrial life of the country has been short it has, of recent years in particular, been intense, so that the total tonnage of ores so far mined is sufficient to form at least a tolerable average.

Fortunately figures of production for the major metals have been kept with at least approximate accuracy. In the Mineral Resources, the Mineral Industry, the Census Reports and the various state and government documents there is material for at least a fairly accurate summation of our production. The figures used below are drawn from these and various additional sources. Where, in the early years, complete figures were not

available, interpolations were made on the basis of averages for years, influenced by the known industrial conditions of the time. The results are not entirely accurate and probably another would not get exactly the same figures, but since the doubt is large only in case of figures of early production when the totals were themselves small, the inaccuracies are believed to be unimportant.

For purposes of the present investigation it was determined to get as nearly as might be the recorded production by districts of the iron, copper, lead, zinc, gold and silver from the beginning of mining to the close of 1904 in the United States. These figures are given below.

IRON.

TOTAL RECORDED PRODUCTION OF IRON ORE (LONG TONS).

Lake Superior district,	293,330,478
Alabama,	45,071,289
New Jersey and southern New York,	24,190,572
Lake Champlain district,	23,250,422
Cornwall mines,	18,405,739
Missouri mines,	6,808,974
	411,057,474

While this does not include all the iron ore raised in the United States it may be safely held to amount to considerably more than ninety per cent. of it. It is difficult to determine how much metal should be taken as the equivalent of this ore. The average yield for the years 1897 to 1901 was practically 55 per cent., and it is not improbable that the lower yield of earlier years on a small tonnage is more than offset by the slightly higher yield of larger tonnage later. Applying, therefore, this factor and reducing the amount to short tons for comparison, the total of 294,754,054 tons is obtained. This represents the total recorded yield of iron for the districts listed above. If this be given a value at $15.00 a long ton, the approximate average of gray forge iron at Pittsburg for a series of years, the value $3,947,712,347 is derived.

COPPER.

Approximately 91 per cent. of the recorded copper production of the United States has come from the three districts listed

below. The values quoted are based upon 12.5 cents per pound. A larger figure could probably have been safely used, but it was desired to be conservative.

TOTAL RECORDED COPPER PRODUCTION
(LONG TONS).

Lake district,	1,521,425
Montana,	1,659,254
Arizona,	680,636
	3,861,315
Estimated value,	$1,081,177,200

LEAD.

The lead production of this country is divided into soft lead and hard or de-silverized lead. From the best available figures the following table has been constructed. The lead is valued at four cents per pound, the approximate average New York price for the last fifteen years.

TOTAL RECORDED LEAD PRODUCTION
(SHORT TONS).

Hard lead,	5,495,431
Soft lead,	1,625,135
	7,120,566
Estimated value,	$569,645,280

ZINC.

Zinc is largely marketed in the form of metal which is called spelter. For present purposes only this portion of the output it taken into account. The total recorded production is 2,235,037 short tons. The value, on the basis of four and one half cents, the average New York price for fourteen years, amounts to $111,153,430.

GOLD AND SILVER.

The figures of gold and silver production are practically those of the mint. They are usually recorded in ounces, but for the sake of comparison with the others are here reduced to short tons. The gold is figured at a uniform value of $20.00 an ounce, and the silver has been given the coinage value for early years with

the commercial value for later ones. Here, as elsewhere, small fractions have been neglected.

ESTIMATED TOTAL TONNAGE AND VALUE OF GOLD AND SILVER.

	Short Tons.	Value.
Gold,	4,353	$2,603,286,360
Silver,	75,530	1,430,374,026

Recapitulating and reducing everything to short tons, the following grand totals are derived:

TOTAL RECORDED METAL PRODUCTION.

Value,	$9,827,501,843
Tonnage,	307,591,518

The different metals contribute to these totals in the following approximate proportions:

PER CENT. OF PRODUCTION.

	Tonnage.	Value.
Iron,	95.80	40.3
Copper,	1.49	11.0
Lead,	2.30	5.9
Zinc,	.40	1.3
Silver,	.00024	26.9
Gold,	.000014	14.6

An examination of this table shows that ores are of two general sorts of which the iron ores and gold ores are representatives. In the one the ore must, in order to be acceptable, contain a large metal content, approximately 50 per cent., or 1,000 pounds to the ton. In the other only a fraction of one per cent., less even than a single ounce to the ton, is necessary to make the ore of equal or higher value. In the one a given unit of value is bulky; in the other it is compact. In the one the value arises from the amount of metal; in the other from the presence of a rare metal. If it were possible to rid the tables of the disturbing influence of gold and silver values in the copper, lead and zinc ores, it is probable that they would be seen to agree more nearly with the iron than the gold and silver ores. To produce an ore which is half metal must mean a large amount of concentration even when account is taken of the fact that iron is relatively abun-

dant in the earth's crust, according to Clark's estimate constituting 4.64 per cent. Though little is known of the amount of lead, zinc or copper occurring minutely disseminated in igneous or sedimentary rocks, it seems probable that ores of these metals can only be produced by much concentration. This may take the form of either powerful agencies operating for a short time or of less powerful ones working through longer periods.

Gold and silver occur in such minute quantities even in rich ores and have been so rarely detected in rocks in general that it would seem necessary in order to bring about their concentration to call in the most powerful agencies, those which act with the greatest intensity. The geographical and geological distribution of the two sorts of ores point to the correctness of this assumption. Iron ores are widely distributed. Gold and silver ores are abundant only in closely circumscribed areas within which special agencies may well be supposed to have acted.

It is common to assume that sedimentary rocks have been formed by the destruction of igneous rocks and whatever may be true of the original rocks of the earth this is doubtless substantially true of the sedimentary rocks now known. To the igneous rocks then we must finally look for the original metals. In the course of their concentration to ores some pass through the intermediate sedimentary form, others do not. It may be profitable to inquire whether the process of sedimentation is on the whole favorable or unfavorable to ore formation.

Sedimentation is but half of a cycle of which erosion forms the complement. By erosion the rocks are mechanically broken down, are in part dissolved and, by the sub-process, transportation, are carried to the scene of sedimentation. Such a process apparently might tend either towards concentration or dissemination of the metallic content of the rocks. It is believed to be an important agent of concentration.

Mechanical sediments are more abundant than chemical ones; the conditions for mechanical precipitation of the material brought to the sea being more widespread than for chemical precipitation. Chemical precipitation does, however, occur. The study of salt and gypsum beds shows that locally and irregularly

the sea deposits its burden of salts. In the case of iron, the most common and hence most easily studied of the metals in question, there is direct evidence of the fact that the sedimentary cycle results in locally concentrating the iron. The black band ores are directly produced by sedimentation and contain notably more iron than in the surrounding rocks or in the rocks destroyed to form them. The Clinton iron ores are another striking example of ores due directly to sedimentary processes. The Lake Superior ores derived from "cherty iron carbonates" and other iron-rich sedimentary rocks are only one step removed from the process. Indeed their final concentration by surface waters is but a portion of the general process of erosion of the present sedimentary cycle. The bulk of the lead and zinc ores of the Mississippi Valley are likewise intimately related to the general processes of the sedimentary cycle and there are excellent reasons for referring the copper ores of the Lake Superior region to the same sort of processes. For the ores which originate through the action of this great general set of always operating agencies the descriptive term *sedigenetic* is proposed. This is intended as descriptive rather than strictly classificatory, since the range of processes is too large to be of much direct benefit in classifying ores.

Opposed to the sedimentary cycle is always the range of igneous activities. While powerful, they are local in their expression. They are intense and violent in their action as compared with the agencies of the sedimentary cycle. They seem eminently calculated to furnish the peculiar conditions, of which heat is possible chief, noted as favorable to the formation of gold ores. Their relation to such ores is furthermore indicated by the widespread association of igneous rocks with gold and silver veins or with lead, zinc or copper ores carrying gold and silver values. It is believed that the igneous agencies and the agencies of the sedimentary cycle form two great antithetical groups and that each is capable of producing certain characteristic ore deposits; the one is characterized by abundance of metal, the other by the presence of scarce metals. To the ore deposits formed under the influence of igneous activities it is proposed

to apply the general descriptive term *igneogenetic*. It is conceived that the two sorts of agencies may act together with all degrees of co-operation, so that there may be sedigenetic, sedi-igneogenetic, igneo-sedigenetic and simple igneogenetic ores. These terms are not proposed to replace such terms as Beck's[1] snygenetic and epigenetic, since it is evident that either sedigenetic or igneogenetic ores may be either snygenetic or epigenetic. The terms are proposed with a view to simply defining what is believed to be the simplest grouping of the major processes which enter into ore genesis.

Having assembled the data and defined the processes which it is proposed to test, it remains to apply the test to the ores whose production has already been given. This can only be done in a very broad way and yet the results are believed to be not without interest.

Among the iron ores, those of Lake Superior, Alabama and Missouri are clearly sedigenetic. Those of Cornwall are perhaps less certainly so, but may fairly be classed as at least sedi-igneogenetic. The Lake Champlain ores are essentially igneogenetic according to Kemp and with them go the New Jersey-New York ores according to Spencer.

Among the copper ores those of Montana are clearly igneogenetic, those of Arizona at least igneo-sedigenetic and those of Lake Superior probably sedigenetic.

The lead ores may for practical purposes be divided, the soft ores being considered as essentially sedigenetic and the hard ores as igneogenetic or possibly in part igneo-sedigenetic.

Of the spelter, that made from Mississippi Valley ores is practically all sedigenetic. That of Colorado is igneo-sedigenetic and that of New Jersey, according to Spencer, igneogenetic. The statistics available do not allow these lines to be exactly drawn, but the best available data indicates a tonnage of 150,001 for the igneogenetic and 1,085,036 for the sedigenetic. The former class will become increasingly important in the future.

The gold and silver may be all considered as igneogenetic,

[1] "The Nature of Ore Deposits," Weed's trans., p. 4.

placer gold being considered here as merely a derived form of vein gold.

Upon this basis the following table has been constructed. It is recognized that the author's grouping may not be approved by all, but it is believed that any changes introduced will not influence appreciably the results.

CLASSIFICATION OF RECORDED METAL PRODUCTION.

	Sedigenetic.		Igneogenetic.	
	Short tons.	Value.	Short tons.	Value.
Iron,	259,371,403	$3,473,824,157	35,382,651	$473,888,190
Copper,	1,734,414	426,008,000	2,667,564	655,169,200
Lead,	1,625,135	130,010,800	5,495,431	439,634,480
Zinc,	1,085,036	97,653,340	150,001	13,500,090
Silver,			75,530	1,430,374,026
Gold,			4,353	2,603,286,360
Totals,	263,815,988	$4,127,496,297	43,775,530	$5,615,852,346

The sedigenetic ores exceed the igneogenetic ores in tonnage approximately in the ratio of six to one while in values the two groups are not especially unequal. The igneogenetic ores are worth somewhat over $125 a ton, while the sedigenetic ores average only $15.65, the iron being so dominant as to practically fix the value per ton. The ratio of value per ton is approximately one to eight.

If the attempt be made to arrange the two groups of processes in the order of their importance, it is evident that in total value there is not much difference. In tonnage the processes of sedigenesis have the advantage while in variety of ores produced in quantity, those of igneogenesis lead.

RECENT PUBLICATIONS ON ALASKA AND YUKON TERRITORY.

ALFRED HULSE BROOKS.

The many papers dealing with the mineral resources of the northwestern part of the continent, published by the United States and Canadian Geological Surveys during the past year, are an index, both to the importance of these resources and to the rapidity of their development. These publications fall into two groups: (1) Preliminary statements of economic results; (2) more complete discussions of certain provinces. In the publications of the first and larger group attempt is made to meet the more urgent needs of the prospector and mining engineer by giving early publicity, in concise form, to the facts, and tentative conclusions of importance to the mining industry. The geologist who caters to this demand for quick results is, of course, in danger of injuring his professional standing by making faulty deductions. If, on the other hand, he defers publication, awaiting more complete data, his conclusions may have lost their commercial application because exploitation has advanced beyond the investigation. If, therefore, preliminary reports are often open to criticism from the standpoint of the geologist and teacher, they have frequently equal, if not greater, value to the mining industry than more exhaustive reports which are delayed in publication.

The advance statements of the Canadian geologists are included in the summary reports of the Geological Survey of Canada. The volume for 1904 of this series has recently appeared, but some of the separate articles were printed many months ago. A praiseworthy feature of this publication is the illustration by maps reproduced in colors. It appears that the Canadians have found means of producing illustrations in colors expeditiously, and in this respect are ahead of the Survey in our own country. The value of this series would be much enhanced

by the inclusion of an index to each volume. While most of the reports are concise statements, some could be condensed without losing anything essential. The publication would gain both in clearness and attractiveness if a more logical and less monotonous form of paragraphing were adopted.

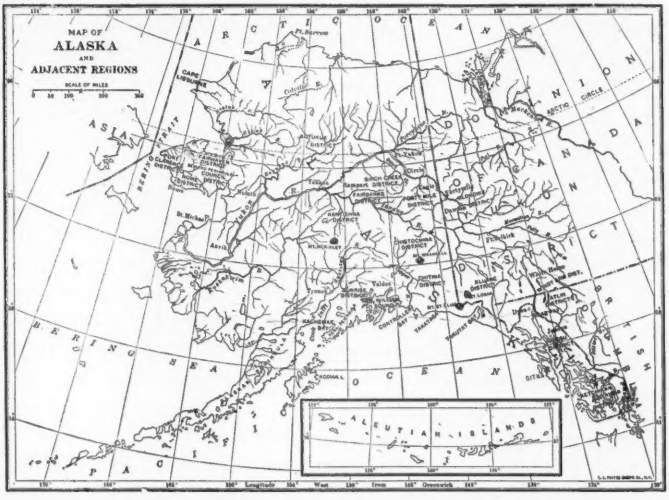

FIG. 29. Map of Alaska and adjacent regions showing the location of mineral-producing districts described in recent geological literature.

The work on the Alaskan side of the boundary is summarized in a publication entitled "Progress[1] of Investigations of Mineral Resources of Alaska in 1904." In this volume of some two hundred pages attempt has been made to present a handy digest of the important economic results. Illustrations are limited to outline maps, one of which shows the distribution of the mineral deposits, so far as known. The bulletin contains thirteen papers written by ten different men. Fifty-two pages are devoted to the gold placers, forty-four to lode deposits, seven to tin deposits, fourteen to the petroleum fields and forty-five to the coal fields. The more important of the papers in this report will be referred to below.

[1] Bull. U. S. Geol. Survey No. 259.

The following discussion of the rather voluminous literature, dealing with economic geology of the northwestern part of the continent, that has appeared during the past six months will be arranged as follows: The publications relating to metalliferous deposits will be first discussed, and they will be taken up by provinces from south to north (see map, Fig. 29). This will be followed by a brief summary of the literature on the coal fields. The limits of this article must perforce necessitate the omission of reference to anything but the more important conclusions.

The bed rock[1] of southeastern Alaska, in a general way, strikes parallel to the coast line, resulting in belts of rather uniform lithologic character, trending northwest and southwest, and complexly folded. These facts are set forth by F. E. and C. W. Wright in the discussion[2] of the recent economic developments in southeastern Alaska. They show that the rocks carrying the ore deposits are altered sediments, with some intrusives, probably of Paleozoic age. Resting on these are some closely folded Mesozoic rocks (Lower Cretaceous) and also some little disturbed lignite-bearing Eocene beds. The metamorphic rocks are bounded on the east by the great Coast Range batholites.

As Spencer[3] has shown, a lode system has been fairly definitely traced along the mainland throughout the belt, though the workable deposits thus far developed are confined chiefly to the northern part of the province. Other less well defined lode systems have been recognized among the islands of the fringing Alexander Archipelago. The gold-bearing lodes fall, according to the Wrights, into four general types: (1) Strong fissure veins of moderate gold contents; (2) mineralized basic dikes; (3) rich, stringer leads; (4) impregnated zones, often of considerable extent, but of low grade. The Treadwell ore body is a special type to be described below. In the Ketchikan district two types

[1] Brooks, Alfred H., "Preliminary Report on the Ketchikan Mining District, Alaska," professional paper U. S. Geol. Survey No. 1, pp. 16–30.

Spencer, A. C., "The Juneau Gold Belt," Bull. U. S. Geol. Survey No. 225, pp. 30–32.

[2] Bull. U. S. Geol. Survey No. 259, pp. 47–68.

[3] Bull. 225, pp. 32–34.

of copper deposits have been recognized: (1) Lenticular masses of copper and iron sulphides, often carrying gold values; (2) contact deposits lying between limestone and grano-diorite, or basic dikes. These are also chiefly sulphides, in places altered to carbonates. Attention is called to the occurrence of workable deposits of gypsum interstratified with Carboniferous limestones on Chichagof Islands.

Dr. Spencer[1] has described in some detail the famous Treadwell ore body. He calls attention to the marked similarity between the geology of the Juneau district and California. The ore bodies are mineralized masses of intrusive albite-diorite, occurring in black slates along the under side of a thick layer of greenstone. The mineralization is later than the Coast Range batholith, the intrusion of which is assigned to the early Cretaceous.

Sulphide impregnation occurs throughout the dikes, but the distribution of values is extremely irregular. The rock is very generally shattered and filled by reticulated veins of calcite and quartz carrying sulphides.

Spencer's conclusions can best be presented in his own words:

"From the structure of the deposits it is evident that the dikes were subjected to pressure which caused fracturing, whereby they became porous, affording channels of easy circulation for underground waters. The minerals in the ores and their mutual relations suggest that carbonated and mineral-bearing solutions found the broken dikes and continued to move through them for a very long period. In transit these waters attacked the minerals of the albite-diorite, decomposing them, and in some cases effecting more or less complete metasomatic replacement.

"The large bodies of gold ore in the Treadwell mines are secondarily mineralized dioritic dikes lying between a hanging wall of greenstone and a foot wall of black slate. The gold accompanies pyrite and other sulphides, occurring both in reticulating seams of calcite and quartz and disseminated through the rock itself.

[1] Spencer, A. C., Bull. U. S. Geol. Survey No. 259, pp. 69–87.

"Feldspar remaining from the original rock consists of oligoclase and microperthite, but these have been largely replaced by albite through the metasomatic action of the vein-forming waters.

"The veinlets occur in two sets of fractures at right angles to each other, which were probably produced by shearing stresses incident upon continental uplifting. Hot ascending solutions, possibly of magmatic origin, have been the cause of mineralization, and the evidence is in favor of only one period of concentration.

"Secondary concentration of the metallic minerals being absent, there is no reason to anticipate any decrease in the per ton value of the ores as greater depths are attained."

The presence of placer gold in the beach sands at Yaktag, which is a wave concentration from glacial deposits derived from the St. Elias Range, is the subject of a brief statement by G. C. Martin.[1] His facts suggest that the gold-bearing series of southeastern Alaska may extend into the unexplored St. Elias Range.

Following the Pacific shore westward, gold is found again in the placers of Kenai Peninsula, where it appears to have its source in a series of highly folded slates and arkoses of undetermined age. These are the subject matter of a paper by Moffit,[2] who also draws attention to some auriferous quartz veins in this district. In a description of the gold occurrence of Shumagin Island[3] G. C. Martin calls into question Becker's determination of the age of this mineralization. He points out that while Becker regarded the mineralization as Miocene or post-Miocene, there is evidence that it may be older. As this locality has been cited in the literature as an example of late Tertiary mineralization, Martin's conclusion is of general interest. On the other hand, Collier, in the same pamphlet,[4] describes some bold-bearing quartz veins on Unalaska Island, at the eastern end of the Aleutian chain, cutting andesites, which are probably of Tertiary age.

[1] Martin, G. C., Bull. U. S. Geol. Survey No. 259, pp. 88–89.
[2] Moffit, F. H., Bull. U. S. Geol. Survey No. 259, pp. 90–99.
[3] Bull. U. S. Geol. Survey No. 259, pp. 100–101.
[4] Collier, A. J., Bull. U. S. Geol. Survey No. 259, pp. 102–103.

The western margin of the Coast Range intrusives has long been known as a locus of mineralization, for this belt includes the famous Juneau district where mining has been going on for a quarter of a century. It is, however, only within recent years that ore deposits have been found along the eastern side of the Coast Range batholites. It now seems probable that the conditions which brought about the ore deposition along the western margin of the granite have repeated themselves along the eastern margin also. The ore deposits of the Salmon River region, near the head of Portland Canal, those of the upper Unuk River basin, and in the placers of the Atlin district, all appear to lie in this easterly marginal zone.

The most recent discovery in this zone, the so-called Windy Arm district, is the subject of a brief description by R. G. McConnell.[1] The ore deposits occur in a basic porphyritic rock, intrusive in a series of crystalline limestones, quartzites and cherts. The limestone is probably the same as that in which Dawson[2] found Carboniferous fossils, and the altered sediments can be provisionally referred to the Paleozoic and correlated with the rocks of southeastern Alaska. The veins which follow well-defined fissures are chiefly in the porphyritic rocks, but have also been found in the slates and granites. Galena is the dominant metalliferous mineral.

Tracing the Coast Range granites northward, they pass inland back of the St. Elias Range, and in the Alsek region evidence of mineralization has again been found near their western margin. Here, in the so-called Kluane Lake region, recently described by McConnell,[3] placer gold has been found near the contact zone. The sediments of this region fall into two groups, the older of which is made up of crystalline quartz mica-schists, probably a part of the great basal sedimentary complex of the Yukon basin. The older group of rocks make up the upland

[1] McConnell, R. G., "Recent Mineral Discoveries on Windy Arm, Tagish Lake, Yukon," Geol. Survey, Canada, 1905, pp. 1–12.

[2] Dawson, George M., "An Exploration in the Yukon District," Geol. Survey of Canada, Annual Report, 1887–88, pp. 170B–171B.

[3] McConnell, R. G., "The Kluane Mining District," Summary Rept. of the Geological Survey Department of Canada for 1904, pp. 1–19.

region, bounded on the south by the St. Elias Range, whose component strata includes a complexly folded series of green schists, slates and limestones. The descriptions suggest a strong similarity between these rocks and those of the mainland strip of southeastern Alaska. Moreover, McConnell provisionally refers this series to the Carboniferous, corresponding in age with that of the southerly belt. This same belt of rocks has been traced northwestward into the White[1] River basin, where it has yielded Permian[2] fossils.

Intrusive rocks are abundant in both the metamorphic series, and the district as a whole appears to be limited on the east by a northward extension of the Coast Range granites. Besides the above described terranes there are also considerable areas of Tertiary sediments and effusives within this province.

Placer gold has been found both in the older and younger metamorphic series and appears to find its source in the bed rock of both groups. This fact is of importance because it appears that here the mineralization of the Permian rocks, identical with those of the coastal region, and of the older schists, similar to those of the Yukon basin, occur close together. It indicates that the mineralization of both horizons is identical in age and possibly closely connected with granite intrusives, which probably took place in early Cretaceous times.

The inland fork of the St. Elias Range stretches northwesterly from the Alsek region across the heads of the White and Tanana rivers, and finally merges with the rugged Alaskan Range. An area lying south of these mountains, including a part of the Wrangell volcanoes, is the subject of a monograph by Mendenhall.[3] Mendenhall's surveys were made on a scale of 1 : 250,000, and hence his results are more detailed and exact than those already considered, but must nevertheless be grouped with recon-

[1] Brooks, Alfred H., "Reconnaissance from Pyramid Harbor to Eagle City," Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, p. 359.

[2] The fossils first referred to the Carboniferous have now been accorded a more definite position in the Permian.

[3] Mendenhall, W. C., "The Geology of the Central Copper River Region," professional paper U. S. Geol. Survey No. 41.

naissance work. Careful choice of excellent illustrations, many diagrams and maps, as well as the clearness and conciseness of the text, characterizes this report throughout. All phases of the various geologic problems presented in this field are dealt with, but this review must confine itself primarily to that part of the paper which bears on economic geology.

Mendenhall devotes some sixty odd pages to general geology, and about forty to economic geology. A series of metamorphosed sediments, chiefly quartz mica schists, with some limestones, forms the basal member of the succession. These appear to belong, in part at least, to the same basal horizon so extensively developed in the Yukon basin. In the northern part of the field a conglomerate slate and a volcanic series form the next higher horizon, and are provisionally assigned to the Lower Carboniferous or the Devonian. In the Wrangell Mountains a series of basic lavas, the so-called Nicolai greenstone, appears as the next higher member of the stratigraphic column, but has not been identified in the northern part of the field. This is succeeded by the Chitistone limestone of Permian or Triassic age. Along the southern front of the Alaskan Range occurs a group of Permian rocks, including sandstone, shales, limestones, and intrusives, with an aggregate thickness of 6,000 to 7,000 feet. These are separated by a fault of probably 10,000-foot throw from the metamorphic sediments on the north and pass underneath the Pleistocene deposits on the south. In this northern part of the field the Tertiary sediments and volcanoes, together with the quaternary deposits, complete the section.

The commercially important minerals thus far found include the placer gold and the various copper ores, and the first of these is of the greatest interest to the present discussion. Mendenhall traced the source of the gold to quartz stringers occurring in the zone of faulting of the Permian shales. It has been suggested above that the mineralized Permian rocks of southeastern Alaska continue northward along the inland front of the St. Elias Range into the White River basin, and it seems probable that these may be identical with some of the Permian rocks described by Mendenhall. In southeastern Alaska the Permian

terranes lie close to the Coast Range batholites, and Spencer has pointed out the probable connection between the intrusives and the mineralization. In the Copper River basin the intrusives are also present in the gold-bearing district, but there are no such great batholites, such as are found in the south, and the sediments are far less altered. This may account for the lesser degree of mineralization. It is at least an interesting speculation as to whether a close relation exists between these intrusives and the mineralization. The theory may be of commercial importance, for the same belt of grano-diorite intrusives is known to appear again in the Alaskan Range to the west and southwest of the region studied by Mendenhall.

The discussion of the copper deposits in this report affords less of interest, as little has been added to what has already appeared in former publications.[1] They appear everywhere to lie close to the contact of the Nikolai greenstone and the overlying white crystalline limestone, called the Chitistone limestone. Mendenhall regards the ore bodies as having been concentrated from widely disseminated material occurring in the greenstone. Two types are described: (1) Vein deposits, including all tabular ore bodies; (2) "bunch" deposits, including those in which the ore is more or less disseminated in irregular masses. The ores are chiefly sulphides, with occasionally some carbonates. In the eastern part of the field native copper has been found in the greenstone, but not in commercial quantities. Since Mendenhall's field studies were completed, one vein of bornite has been followed to a depth of one hundred feet.

The copper deposits of Prince of Wales Island[2] are closely associated with basic igneous rocks, and some of them lie along the contact between limestones and intrusives. Beyond these

[1] Schraeder, F. C., and Spencer, A. C., "The Geology and Mineral Resources of a Part of the Copper River District," U. S. Geol. Survey, special publication, 1901.

Mendenhall, W. C., and Schrader, F. C., professional paper U. S. Geol. Survey No. 15.

[2] Brooks, A. H., "Preliminary Report on the Ketchikan Mining District, Alaska," professional paper U. S. Geol. Survey No. 1.

Wright, F. E. and C. W., Bull. U. S. Geol. Survey No. 259, pp. 61–64.

broad facts of occurrence, there appears to be no basis for comparison between them and those of the Copper River region. It is a significant fact, however, that both fields appear to lie in the same general geologic province.

The reports of a second group, here to be discussed, deal with the placer fields of the Yukon basin and the Seward Peninsula. Though there are too many gaps in our knowledge of this vast province to permit of a definition of the auriferous bed-rock series, it seems probable that the gold finds its source in a complex of metamorphic sediments which are intruded by igneous rocks of various types. This basal sedimentary group, already referred to, has a wide distribution in the Yukon basin. Its age is, for the most part, pre-Devonian and probably chiefly Silurian or Cambrian. But little detailed investigation of these rocks has been made, but a number of preliminary reports treating of them have recently appeared.

McConnell's second report[1] on the Klondike district is a very welcome contribution to our knowledge of the geology of the Yukon basin, being in fact the first detailed account of any of this field which has appeared in print. A geologic map and section, and a map showing distribution of auriferous gravels, both on a base of two miles to the inch, with two hundred-foot contours, as well as a number of half-tones and diagrams, well illustrate the publication. About one half of the pages are devoted to a detailed description of the placers of the creeks, and with these this writing is not concerned.

The oldest rocks of this field, as in other parts of the Yukon basin, are a group of schists of sedimentary origin, with some crystalline limestones highly metamorphosed and closely folded, called by McConnell the "Nasina series." These are described as occurring in a broad syncline within which is included another great schist series, probably all of igneous origin. These latter, forming the so-called "Klondike series," are chiefly sericite, with some chloritic schists representing alteration products of quartz porphyries, granite porphyries, and basic porphyritic rocks,

[1] McConnell, R. G., "Report on the Klondike Gold Fields," pt. B, Ann. Rept. Geol. Survey of Canada, Vol. XIV., pp. 1b–71b.

with some tuffs. These rocks appear, for the most part, to be intruded in the Nasina series, but have been so deformed that their relations are difficult to establish. The Klondike series is of importance in being the locus of the auriferous deposits from which the placer gold has been derived. In this respect the Klondike district differs from the other placer fields of the Yukon, where the gold appears to find its source in the altered sedimentary schists.

McConnell his differentiated a third series of rocks under the name "Moose-hide group." These are essentially altered basic intrusives, varying from diabases to serpentines. They are believed to be of contemporaneous age with the Klondike series and beyond being somewhat more massive appear to differ little from the basic members of the latter. The reason for making a distinct stratigraphic unit of the Moose-hide rocks is not apparent from the evidence presented.

The younger rocks of the area include Tertiary volcanics and sediments which rest unconformably on the metamorphic rocks. Under massive igneous rocks are described granites, whose age has not been determined, together with diabases, andesites, etc., which cut the Tertiary beds.

The auriferous gravels are divided into three groups. The first and youngest embraces the gulch, creek and river gravels of the present drainage courses. Next in age are the terrace gravels found along the slopes of the present water-courses. The oldest are the gravels of an abandoned drainage system, which include "river gravels" and "white channel gravels."

The first merits no special mention here. The terrace gravels which indicate interruption in the dissection of the present valleys are found at various altitudes. The high level river gravels, marking the lines of old water-courses, consist of well-rounded pebbles of a heterogeneous character, together with sand, and, except for their elevated position (four hundred and fifty feet above the present water ways) and depth (one hundred and fifty to one hundred and seventy-five feet) do not differ greatly from the alluvium of the present drainage channels.

The white channel gravels consist largely of quartz pebbles,

often including angular and subangular boulders two to three feet in diameter. They include some decomposed schist pebbles and exhibit little evidence of sorting. Their origin is ascribed to ancient creek deposits. These beds have a depth of from one hundred to one hundred and fifty feet and are preserved as remnants along the slopes of the present valleys. McConnell ascribes their accumulation to slow deposition in streams of low gradient, but this does not appear to account for the predominance of quartz or the presence of the large boulders. He regards their age as Pliocene or older, and suggests that the leached condition of the schist pebbles indicates a warmer climate while these were being deposited. These white channels have proved an important source of gold in the Klondike region.

Auriferous quartz veins are not common, but have been found at a number of places cutting the Klondike series. These are usually of lenticular form and not more than a few inches in thickness. Larger veins (usually barren) several feet in thickness have been found, but have not been traced far and appear to be rather lenticular masses than continuous veins. The metallic contents of the veins are iron and copper, pyrite, galena and free gold. There appears to be a genetic relation between these quartz veins and some pegmatite dikes found in the district. Feldspar crystals were found in the quartz veins, and in one instance a transition between a pegmatite and a quartz vein was noted.

Mr. McConnell believes that the placer gold has been derived from a large number of disseminated quartz veins, rather than from individual rich lodes, and the outlook for quartz mining, therefore, does not appear to be hopeful. He estimates that the value of the gold contents of the gravels of the district, including what has been extracted, is $200,000,000. As the total production up to the close of 1905 is about $100,000,000 and the annual output now is less than half of the maximum attained in 1900, it is evident that the district is on the decline. Nevertheless, as McConnell points out, much of the remaining gravel can be exploited, provided the necessary investments for bringing in water under gravity are made.

Though up to the present time no districts have been found in the Yukon territory which compare in richness and extent with the Klondike, yet workable placers have been found at a number of other localities. One of these camps, called the Duncan Creek district, has been recently described by Joseph Keele[1] of the Geological Survey of Canada. Most of his report is devoted to a detailed description of the placers, but the notes on the geology are of general interest. A drainage map accompanying the reports shows the district to lie about two hundred miles east of Dawson and close to the front ranges of the Rocky Mountain system. The bed rock geology appears to be identical with that of the Klondike district. There is here the same schistose series, made up of altered sediments, succeeded or intruded by the quartz sericite schist and chloritic schists believed to be altered quartz porphyries. Intrusive dikes of dioritic granite and andesite rocks are not uncommon. As in the Klondike the gold is believed to have its source in disseminated stringer leads rather than in rich lodes.

The gold-bearing rocks of the Klondike stretch westward across the boundary into Alaska and broadening out somewhat form the source of the placer gold of a number of different districts. Mr. Prindle has presented his preliminary conclusions on this field in a report[2] recently issued. This publication is illustrated by topographic maps and half-tones, as well as by a geologic sketch map. About half of its pages are devoted to more or less detailed descriptions of the placers on the various creeks.

Two groups of metamorphosed sediments are differentiated on the map, the older of which consists chiefly of quartz mica schists, with belts of crystalline limestones which are of pre-Devonian age. This group of rocks can be regarded in general terms as the equivalent of McConnell's Nasina series. In the

[1] Keele, Joseph, "The Duncan Creek Mining District," summary report Geological Survey, Department of Canada for calendar year 1904, pp. 18–42.

[2] Prindle, L. M., "The Gold Placers of the Fortymile, Birch Creek, and Fairbanks Regions," Alaska, Bull. U. S. Geol. Survey No. 251.

text, following Spurr's[2] classification, Mr. Prindle has made two sub-divisions of this group, the older being the Birch Creek schists, containing only subordinate amounts of limestone, and the younger, the Forty-mile formation, embraces a series of crystalline limestones which appear to rest conformably on the Birch Creek schists.

A succession of limestones, slates, cherts, quartzites, together with diabase, serpentines and tuffs, have been mapped under the designation of Rampart formation. This second group of partly metamorphosed rocks appears to rest unconformably on the older and is, in part at least, of Devonian age. The igneous rocks of this terrane have a similarity with McConnell's Moosehide group, but the sediments do not appear to be represented in the Klondike district. In a stratigraphic table of the Yukon region Prindle includes sediments of Mississippian, Permian and of both upper and lower Cretaceous age, but confines his text to the older metamorphic terranes and to the so-called Kenai formation, a coal-bearing series of Eocene age.

A series of gneissoid and schistose granites are provisionally assigned to the Archean under the name Pelly gneisses, but are more probably altered intrusives in the sediments. From the description some of these rocks resemble the Klondike schists of McConnell. As massive intrusives Prindle describes granites, diorites, gabbros and diabases. The Rampart formation includes many basalt flows. The occurrence of recent olivine basalts is also noted.

The Quaternary deposits are divided into bench and stream gravels. In the Forty-mile region, where benches are specially prominent, they occur at from two hundred to two hundred and seventy-five feet above the stream beds, and some have been found to carry placer values. Detailed mapping will probably enable the correlation of these high bench deposits with some of those described in the Klondike district. There must undoubtedly have been an older drainage system, the tracing out of which may be of far-reaching importance to the placer miner.

[2] Spurr, J. E., "Geology of the Yukon Gold District," Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 140–155.

The Birch Creek schists form the country-rock of much the larger part of the Yukon-Tanana region, and the quartz veins in these schists appear to be the source of most of the placer gold. Prindle's results point to the same conclusion regarding the source of the gold as McConnell's, namely, that much of the gold has been derived from quartz stringers and is disseminated in the bed rock rather than concentrated in rich lodes. He observed one impregnated zone in a mass of quartz diorite, a sample of which yielded gold values with some silver.

The so-called Rampart region, also a part of the Yukon-Tanana gold field, is briefly described by Messrs. L. M. Prindle and F. L. Hess.[1] Though the review of this work should await the appearance of the more complete report now in press, it is worth while to note that the same geologic conditions here prevail as are described in the other districts to the east. The basal rocks are altered sedimentary schists succeeded by Devonian beds which are less altered. Unlike the Fairbanks district granitic intrusions are here abundant. Some high bench gravels are provisionally assigned to the Pleistocene. The evidence points to the derivation of the placer gold from small quartz stringers in the metamorphic rocks.

The production of the Yukon-Tanana region which in 1904 was probably about a million dollars in 1905 became the largest of any in Alaska with an output of probably nearly seven million dollars. This large increase is entirely due to the very rapid advance of mining in the Fairbanks district, whose output leaped from about half a million in 1904 to about six million in 1905. With improvement of transportation facilities and mining methods, where auriferous gravels of lower grade can be handled, this province should become one of the great gold producers of America.

The metamorphic rocks of the above described field have been traced westward as far as the Yukon, beyond which the region has been only partially mapped. It is certain, however, that much of this region lying between the Yukon and the Seward Penin-

[1] Prindle, L. M., and Hess, F. L., "Rampart Placer Region," Bull. 259, pp. 104–119.

sula is occupied by Mesozoic and Tertiary terranes. In view of this fact probably no correlation tracing in the field between the Yukon-Tanana and the Seward Peninsula can be made, and all hope of correlation must depend on paleontologic determinations. Unfortunately the Yukon-Tanana metamorphic rocks have not yet yielded any fossils. In the Seward Peninsula the gold-bearing rocks are less altered, and have yielded some Silurian fossils. In both fields there is a general similarity in stratigraphic succession, which suggests that the terranes are of the same age.

The results of a survey of the northeastern part of the Seward Peninsula are presented in a report by F. H. Moffit.[1] Of the eighty odd pages about half are devoted to the geography and geology. A topographic and a geological reconnaissance map, together with half-tones and text figures, illustrates the publication.

The metamorphic rocks, divided into two groups, the schists and the limestones, are, in part at least, Silurian. In some of the area a massive crystalline limestone was found to underlie the more schistose rocks, including quartz, calcite and mica schists, with some thin-bedded limestone. The mapping was, however, of a reconnaissance character, and as the structure is complex, no very definite stratigraphic results were obtained. There is some evidence of a dome structure which Moffit suggests may be brought about by the intrusion of granite stocks, which are not uncommon. A younger coal-bearing series occurs in small areas in this province. The study of metamorphic terranes is rendered difficult by the recent extrusions of basalt.

The gold thus far mined has been found in the gravels of the present streams. Some evidence of an older drainage system is found in the presence of some high terraces up to altitudes of five hundred to six hundred feet. The source of the placer gold is assigned to small quartz veins and stringers and impregnated zones in the bed-rock terranes. The total production of this field up to 1903 was less than half a million dollars. Its isola-

[1] Moffit, F. H., "The Fairhaven Gold Placers, Seward Peninsula," Bull. U. S. Geol. Survey No. 247.

tion has prevented the expansion of the mining industry fully warranted by values thus far found.

The writer[1] has elsewhere pointed out that in Alaska coal has been found in at least four, possibly five, different systems, ranging from the Carboniferous (Mississippian) to the Tertiary (Eocene). While much remains to be done in correlating these various coal-bearing strata, important light has been thrown on the problem by some recent publications. In connection with this work the oil fields have also received some attention.

Dr. Martin has made reconnaissance surveys of some of the more important coal and oil fields[2] of the Pacific seaboard. In a report[3] on these surveys, which contains a number of sketch maps, showing both topography and geology, two distinct provinces are discussed. First, the petroleum and coal districts, which lie between Mount St. Elias and the mouth of Copper River, and second, the petroleum bearing region which stretches along the eastern coast of the Alaska Peninsula and northward into Cook Inlet.

Though in the eastern province, generally called Controller Bay region, oil seepages have long been known, and high grade coal since 1898, it is only since 1901 that any systematic prospecting has been done. During the past four years some fifteen wells have been drilled, in two of which a small flow of oil was met with. Systematic development of the coal is now under way.

In this district the succession of bed-rock formations, according to Martin, is as follows: A basal series of metamorphosed sediments of undetermined age unconformably overlain by the Katalla formation, tentatively referred to the Eocene. These are overlain by coal measures (Kushtahkah formation) which are probably Eocene or Oligocene. The same area also includes some marine Miocene beds. Some intrusives are present through-

[1] Brooks, A. H., "The Outlook for Coal Mining in Alaska," *Trans. Am. Inst. Min. Eng.*, 1906, pp. 683–702.

[2] Martin, G. C., "The Petroleum Fields of the Pacific Coast of Alaska with an Account of the Bering River Coal Deposits," Bull. U. S. Geol. Survey No. 250.

[3] A brief statement of the additional knowledge gained by a second season's field work is contained in Bull. No. 259, pp. 128–150.

out the succession. The basal sediments are intensely deformed and the younger beds are closely folded and faulted. The prevailing strikes in the oil and coal fields are northeast and southwest.

The petroleum seepages fall into three lines which are parallel to the dominant bed-rock structures. But little of the drilling has been done with any regard to structure and is hardly a fair test of the presence of oil pools. Though the drilling thus far has been rather discouraging there still remains here a legitimate field for prospecting.

The coal seams occur in deformed rocks, but nevertheless can be successfully mined. Martin's examinations show that in this district there are many workable seams of high grade, varying from a bituminous to a semi-anthracite coal.

Mr. Stone[1] has briefly summarized the known facts regarding the Cook Inlet and Alaska Peninsula regions. He points out that most of the coals are lignitic and occur in the so-called Kenai series (Eocene or Oligocene), which is typically made up of fine conglomerate sandstone, shale and clay. Some higher grade coals found at a few localities are provisionally referred to the upper Cretaceous. These upper Cretaceous rocks have been studied in greater detail by Messrs. Stanton and Martin,[2] who describe them as made up of shales and sandstones, with some heavy beds of conglomerate. In the same report they present a valuable résumé of the Mesozoic and Tertiary stratigraphy of this field, which is as follows:

Tertiary Kenai formation, now marine shales, sandstones, and conglomerates, 200 feet ±.

Unconformity.

Upper Cretaceous. Similar to Kenai, but including some marine shales and sandstones, 1,000 ±.

Unconformity.

Lower Cretaceous. Shales and sandstones.

[1] Stone, R. W., "Coal Resources of Southwestern Alaska," Bull. U. S. Geol. Survey No. 259, pp. 151–171.

[2] Martin, G. C., "Mesozoic Section on Cook Inlet, Alaska Peninsula," *Bull. of the Geol. Society of Am.*, Vol. 16, 1905, pp. 391–410.

Unconformity.

Upper Jurassic. Naknek formation. Conglomerate, arkose, sandstone and andesite flows, about 5,000 feet.

Middle Jurassic. Enochkin formation. Shales and sandstones, with some conglomerate beds, 1,500 to 2,500 feet.

Unconformity. (Probably conformable on Lower Jurassic when that is present.)

Lower Jurassic. Tuffs and sandstones, 1,000 feet ±.

Unconformity.

Upper Triassic. Cherts, limestones and shales, with many intrusives, 2,000 feet +.

(Base not seen.)

This is the only locality in Alaska where the Mesozoic section has been studied in any detail, but most of the formations listed have been found in other parts of the province. In the Mount Wrangell region Triassic shales and limestones are found[1] to rest conformably on limestone provisionally referred to the Permian. The Triassic beds are succeeded unconformably by the conglomerates, sandstones and shales of the Kennicott formation of Lower Cretaceous age. In this section, therefore, the etnire Jurassic system would appear to be wanting. Some two thousand feet of Middle (?) Jurassic rocks were found by the writer in the Alaskan Range and these rest unconformably on beds which are probably Triassic. In the same province are two thousand feet ± of coal-bearing strata, provisionally assigned to the Eocene. All of this goes to show that the Mesozoic and Tertiary horizons are extensively developed in the Pacific region of Alaska.

Mr. Collier[2] has described two series of coal-bearing rocks near Cape Lisburne in the extreme northwestern part of Alaska. The older series includes bituminous coals occurring in rocks of Missippian age and is the first account of Carboniferous coals west of the Rockies. A great series of Jurassic coal measures

[1] Mendenhall, W. C., "Geology of the Central Copper River Region," professional paper U. S. Geol. Survey No. 41, p. 152.

[2] Collier, A. J., "Coal Fields of the Cape Lisburne Region," Bull. U. S. Geol. Survey No. 259, pp. 172–185.

is also described carrying a bituminous coal of a fair grade. This district, while it probably has little immediate commercial value, is of geologic interest and represents a possible source of fuel when the more accessible fields are exhausted. The statement already published is to be followed by a more complete report now in print.

IRON ORE RESERVES.

CHARLES KENNETH LEITH.

The great increase in the world's annual consumption of iron, together with the attempts of large interests to acquire the known iron ore reserves, have led to careful inventories of the world's supply of iron ore, its rate of depletion, and to speculations as to further supplies. Estimates of the time of exhaustion of the present known supply have varied widely, but have shown startling agreement in the short time assigned. During the present year there have appeared several discussions of the subject which merit especial attention.[1]

Professor Törnebohm estimates for the Swedish government the iron ore reserves of the world by countries, based on detailed figures for the individual districts, as follows:

	Tons.	Metallic Iron. Per Cent.
United States,	1,100,000,000	45 to 67
Great Britain,	1,000,000,000	25 to 34
Germany,	2,200,000,000	30 to 45
Spain,	500,000,000	40 to 56
Russia and Finland,	1,500,000,000	20 to 65
France,	1,500,000,000	
Sweden,	1,000,000,000	50 to 70
Austria-Hungary } Other countries }	1,200,000,000	
Total,	10,000,000,000	

[1] Presidential address, by R. A. Hadfield. Delivered at the annual meeting of the Iron and Steel Institute at London, May 11, 1905. *Journ. Iron and Steel Inst.*, Vol. LXVII., No. 1, 1905, pp. 27–106.

"The Iron Ore Supply of the World," by Professor Alfred Törnebohm, *Teknisk Tidskrift*, September, 1905. Translated in *The Iron Age*, November 2, 1905, pp. 1158–1160.

"The Exhaustion of the World's Metals," by N. S. Shaler, *International Quarterly*, Vol. 11, 1905, pp. 230–247.

"A Word Survey of Iron and Steel, by J. Stephen Jeans, Secretary British Iron and Steel Institute.

"A Blue Book of Iron Ore Deposits in Foreign Countries," by Llewellyn Smith. Compiled at the Board of Trade from diplomatic and consular reports, London, 1905.

Many will be surprised at the high figures given for the reserves in Great Britain and European countries. So much is heard of our own vast reserves and of the low grade of some of the foreign ores that we have come to think of the supply outside of North America as relatively small. The position of the United States is somewhat better than shown in the table when we take into account the grades of ore. By multiplying the figures by the average percentages of metallic iron given for each of the countries by Professor Törnebohm the result is as follows:

	Tons of Metallic Iron.
United States,	603,166,600
Great Britain,	295,000,000
Germany,	825,000,000
Spain,	249,375,000
Russia and Finland,	637,500,000
Sweden,	611,538,460

It is believed that the reserves for the United States, and hence the total, are higher than indicated in this table, but before taking up this question, we may consider conclusions that may be drawn from the figures as they stand.

President Hadfield of the British Iron and Steel Institute has prepared a diagram showing the world's increase of pig-iron consumption since the fifteenth century and the projection of this rate for the next century on the rate of the last thirty years. If the same rate of increase hold for the next century as has held for the last thirty years, in the year 2,000 the world's annual consumption of iron will be three and one-fourth times its present consumption. The total world's supply of iron ore now known, given as 10,000,000,000 tons by Törnebohm, will be exhausted in about fifty years. If the total be correct, about one quarter of the world's known reserves have been used to the present time.

It is argued that the calculated rate of increase is not improbable because of the increased rate per capita of the countries now using iron, because of the normal increase of the population of these countries, and because of the extension of the uses of iron through a much larger proportion of the world's popula-

tion than now uses it (12½ per cent.). If 38 per cent. of the world's population were to require iron in the year 2,000, this would account for the calculated increase of consumption.

However, this additional part of the world's population, especially in Asia, may find its own iron ore supplies. No one would doubt that the world's reserves will be greatly increased by new discoveries in these relatively unexplored parts of the world.

Judging from the history of the development of the iron ore industry to the present time, the reserves of unexplored countries are likely to be developed only so fast as the population requires it. In this case, such new discoveries will not figure in the reserves available to the countries at present producing iron ore. The generalization might perhaps be made that each continent must ultimately depend on its own resources of iron ore and cannot count, to any large extent, on drawing supplies from other parts of the world.

It is of interest to apply the same method of calculation used for world's supply and consumption to the United States. If the rate of increase of consumption be projected for the next one hundred years on the basis of the increase for the past thirty years, that is, the period used by President Hadfield, and the lines superposed upon his diagram, it would appear that the rate of increase of production for the United States is greater than that of the world. Also the rate of production for the United States is greater than that of any other country. With the total reserve of iron ore in the United States estimated by Törnebohm at 1,100,000,000 tons, the supply would be exhausted in less than twenty years if the calculated rate of increase of production holds. With the reserve estimated by Törnebohm, up to the present time 39 per cent. of our total supply has been used, and 29 per cent. has been produced during the last thirty years.

The late Edward Atkinson estimated that if the per capita consumption remains the same, the average annual increase in population of two millions for the United States calls for a yearly increase of pig iron of half a million tons, and that when the probable increase in per capita consumption is taken into account,

the total production of the United States will increase at a considerably greater rate.

Professor Shaler concludes that the iron ore supplies of the United States are not likely to last for more than a century.

Others have reached similar conclusions as to the relatively early exhaustion of the ore deposits, few venturing to predict a longer life for the known deposits of more than one hundred years. The strenuous efforts of larger interests in recent years to secure ore deposits and to explore ore-bearing fields are evidence that the possibility of the early exhaustion of the ores is appreciated by many of the companies most concerned.

The situation is probably not so unfavorable as the above estimates would indicate. The assigned rate of increase of production may be too great, for the development of the iron industry of the United States for the past thirty years has been a phenomenal one. On the other hand, it is scarcely safe to predict a lessening rate of increase, for during the past fifty years it has been thought many times that the increase of rate was checked.

Törnebohm's estimate of the total reserves of iron ores for the United States is very conservative, and probably should be greatly increased. His estimate is confined to the producing districts and leaves out of account many important extensions of the ore deposits and districts, many known deposits of good size and quality not now mined because of location or other causes, and large reserves of ore which in the United States are regarded as too low grade to be of present commercial value, but really of a higher grade than ores counted in the English and German reserves. There should also be included the iron ore resources of Canada and Mexico immediately adjacent and accessible to the United States, already largely controlled by American capital and probably to be used in part in the United States.

The ultimate iron ore resources of North America are still far from known, but there may be no harm in reviewing our present imperfect state of knowledge concerning them.

A great bulk of the known reserves of the United States is in the Lake Superior region. Törnebohm assigns a billion tons

to the Lake Superior region, and these figures, while probably small, are in accord with many current estimates. In the producing Lake Superior iron districts exploration has, for the most part, been sufficiently thorough to make it certain that no large increase of reserves is to be expected. In the Mesabi Range, for instance, thirty thousand drill holes and pits have been sunk. The Lake Superior iron districts, however, make up but a small proportion of the region tributary to Lake Superior, constituting less than four per cent. of the land area included in the United States Geological Survey's map of the Lake Superior region. In the remaining 96 per cent. there are still large possibilities for finding iron ores. The greatest of the ranges was discovered as late as 1891 and within the last four years two entirely new ranges have been found, though neither of them yet of the first importance. The geological conditions are such as to warrant the belief that more may be found. At the present time exploration in areas intervening between the ranges and in outlying areas is being pushed vigorously, showing the faith of iron men in further possibilities in this direction. The most sanguine, however, would scarcely hope to find ores equal in amount to those already known.

Lake Superior geological conditions are known to extend northward and northeastward through Ontario, suggesting an important source of supply here. The present known iron ore supply of this great region, counting even ores of low grade, does not equal the reserves of one of the older Lake Superior districts, such as the Marquette, but the country still to be explored is so vast that it is not unreasonable to suppose that important iron ranges such as those of the Lake Superior region may be found. Nevertheless, it is true that nowhere in the Lake Superior country where an equivalent amount of exploration has been done have the results been so disappointing.

When the present high grade deposits of this and other countries are exhausted, the future demand for iron ore is likely to be met by the use of far lower grades than are now considered commercially profitable. The term "ore" is a relative one. With the conditions in Alabama a rock containing 36 per cent.

metallic iron may be mined as ore, while in the Lake Superior country such rock is now of no value as an ore. The ferruginous cherts and jaspilites, making up 95 per cent. or more of the iron formations of the Lake Superior region, average between 25 and 35 per cent. in metallic iron, and show all gradations into the iron ores. At the present time ores running below 45 per cent. are but rarely shipped. If the time should come when 30 per cent. ore could be used under the Lake Superior conditions, the tonnage available would be something enormous, perhaps twenty or more times as great as the present supply. It should be remembered that these ores are high in silica, and therefore not as desirable as ores of the same metallic content containing calcium carbonate in the gangue as do the Alabama ores. Moreover, the great distances from blast furnace centers, on the assumption that these remain approximately fixed, will put the low grade Lake Superior ores to a disadvantage in the matter of the cost of transportation.

Törnebohm estimates the amount of ore now available in the southern Appalachians at 60,000,000 tons. The Clinton red hematites make up the bulk of this tonnage. Drilling has shown that the presently worked deposits extend with slightly leaner but uniform composition in thin even beds over enormous areas, and it is altogether likely that the tonnage of these ores is many fold the figure given.[1] The ores are low grade and the cost of mining will greatly increase when the larger reserves are tapped.

The Clinton ores extend along the Appalachians into New York and appear again in Nova Scotia and Newfoundland. In each of these localities extensions are likely to be found. At Belle Isle, Newfoundland, approximately 30,000,000 tons of iron ore are available. This body is known to extend under the ocean, and if it can be successfully mined there, a large additional tonnage may be secured.

The brown ores of the eastern United States are difficult to estimate. They are usually low grade, mixed with clay, and often lie in thin and irregular beds, but the aggregate amount is large.

[1] E. C. Eckel estimates 1,000,000,000 tons of red ore above the thousand-foot level in Alabama alone. (Engineering Magazine, Vol. XXX., 1906, p. 521.)

The magnetites of the Adirondacks and New Jersey are not included in Törnebohm's figures. Here again the tonnage is large, and if attempts at magnetic separation are successful on a large scale, as they seem likely to be, we have here another important source of iron ore which has not been taken into account in these estimates.

The titaniferous magnetites will be another important source of supply when they can be profitably smelted.

Unexploited iron ore deposits are widely distributed in the western United States and extravagant estimates of tonnage have been reported, frequently due to the fact that the basis of comparison has been the comparatively small size of the precious metal deposits of the West. The writer has examined deposits of reputed large size where the true tonnage seemed to him to be measured in units of thousands rather than millions or tens of millions. The grade of these deposits is on the average not high as compared with Lake Superior deposits and there is frequently a high percentage of phosphorus and sulphur. Nevertheless, there is in the aggregate through the western states a very large tonnage of iron ore of present commercial grade.

Among the better known deposits might be mentioned those in the Hartville district of Wyoming and in Fierro, New Mexico, both of which are now being drawn upon, in Pitkin, Chaffee, Saguache, Lake and Gunnison counties, Colorado, in Iron county, Utah, in northeastern Washington, and in a number of localities in the Great Basin region of Nevada and California. There should be included also the ores of Vancouver and Texada Islands in British Columbia, which are largely controlled by American capital and will be used in the United States. The same remarks may apply to the Durango and other Mexican deposits. With few exceptions, the western ores occur along the contacts of intrusive igneous rocks and limestone, and the extent to which the ores follow the contact in depth has not been shown. Hence the estimates of tonnage vary within very wide limits. The iron ore deposits of Iron county, Utah, are among the larger and most typical of this class of ores. Here some eight hundred pits have been sunk and it has been possible in recent

detailed mapping to estimate with a reasonable approach to the truth the amount of ore of all grades appearing to the depth shown by explorations or natural exposures. Using the Utah deposits as a basis of comparison, and excluding the Mexican deposits which the writer has not seen, the tonnage of iron ore of all grades in each of the better known districts of the west and adjacent parts of British Columbia would not surpass that of one of the older Lake Superior ranges, but it is extremely likely that as deep exploration of the presently known deposits continues, and as further deposits are found, as they undoubtedly will be, that the aggregate tonnage of ore in the west will equal a considerable part of that of the Lake Superior region, and one would be rash to conclude that it is impossible that an amount of iron ore may be found in the west fully equivalent to that in the Lake Superior region.

If these data approximate the truth, there seems to be little cause of alarm that North America will really suffer for lack of iron ore for a considerably longer period than required for the exhaustion of the presently known tonnage, as estimated by Törnebohm and others, at the present rate of increase of production. The time of exhaustion is not likely to come before that calculated on the same basis for the world's reserves, and probably not then. It may be argued that the use of lower grade ores in Europe and England than in the United States is itself evidence that the exhaustion of reserves is farther in the future for the United States than for Europe or England. But as it becomes more and more obvious that the end of the supply of higher grade ores in the United States is not indefinitely in the future and may even be within a single lifetime, there is likely to be an increase in the tendency to conserve the higher grade ores, and especially the Bessemer ores, and draw more largely on the lower grade supplies, a tendency favored by the concentration of control in a few hands. This tendency has already become well defined as shown by the fact that pig iron production has not in recent years increased as rapidly as iron ore production. It is not at all unlikely that even the next decade may see important changes in this direction. This will give value to

properly located low grade ores. It will ultimately mean higher cost for iron, changes in the relative importance of processes for conversion of iron, possible changes in the geographic distribution of different phases of the iron industry, and a modification of the relations of the North American iron trade with that of the rest of the world.

Professor Shaler concludes[1] that when the higher grade deposits of the world have been exhausted "the cost of production will gradually increase as the lower grade ores and those remote from coal come into use. In the end we shall have to resort to concentrating processes by which the iron ore is separated from the rock in which it is disseminated as grains. This upward grade in cost means a downward grade in the utility of the metal in the service of man. Finally, it may be some centuries from now, but surely we shall be forced to an economy in the use of the metal such as was exercised by folk two hundred years ago, when, save for what went down at sea, or rusted back to earth, none of it was lost to the arts. In this stage, when it becomes again a precious metal, iron may continue to be the helper of man for an indefinite period, but its power for help will be greatly diminished."

[1] *International Quarterly*, Vol. II, 1905, pp. 230–247.

THE SOUTHERN KLONDIKE DISTRICT, ESMERALDA COUNTY, NEVADA.—A STUDY IN METALLIFEROUS QUARTZ VEINS OF MAGMATIC ORIGIN.[1]

JOSIAH EDWARD SPURR.

LOCATION.

Several years ago, before the discovery of ore at Tonopah, Nevada, ore was found and mined about nine or ten miles south of this now flourishing district. The production of the older camp has never been great, so that it is little known, but the geological features of the ore deposits and their petrographical relations to the surrounding rocks, inasmuch as they bear directly on certain questions of genesis, are of great scientific interest.

There are two main portions of the district, the Southern Klondike proper and East Klondike, separated by an interval of about a mile.

The occurrence, which it is the purpose of this paper to describe, is located in the Southern Klondike camp proper. In the East Klondike region the ore is associated with Tertiary rhyolite and will not be further considered.

GEOLOGY.

The country rocks of the Southern Klondike region include sediments, volcanics and granitic intrusives. The district is situated within an area of Palæozoic limestone whose exact age is unknown but which is thought to be Cambrian or Silurian, owing to its analogy to similar rock of determined age in adjacent regions (as at Silver Peak). The limestone area, so far as known, is not more than a few miles in diameter and is surrounded by Tertiary volcanics, chiefly rhyolite.

At the Klondike mines the limestones are cut by a long, dike-like intrusion of a peculiar granitic, highly siliceous rock, which will

[1] Published by permission of the Director of the United States Geological Survey.

be later described. At a distance from the intrusive the limestone is of a fine blue color, sometimes crystalline, often thin-bedded and slaty. As one approaches the dike, especially where this is thickest, the sediments are seen to be highly metamorphosed. Some of the limestone has been altered to marble and the slaty portions have been changed to knotted and spotted schists and dense siliceous hornstone. Microscopic study shows that the schists and hornstones are composed of quartz, muscovite, calcite, epidote, garnet, etc., in varying proportions. In one variety of spotted schist the spots consist of fibrous green amphibole.

NATURE OF THE GRANITIC INTRUSION.

The granitic intrusion, as shown on the map (Fig. 30), extends for nearly a mile with a general course of N. 60° E. and a northwest dip. It has an average thickness of about 15 feet and for most of its course is nearly straight. On the southwest end it terminates in an irregular knob, about 100 yards in its longer, and about one-third as much in its shorter diameter. At the northeast end the dike is cut off by Tertiary rhyolite. It is therefore probably pre-Tertiary in age.

The granitic rock is lithologically of a varied character. Some portions are very fine-grained and others coarse, the two textures grading rapidly into one another. It contains nests of pegmatite, which pass by transitional stages into masses and veinlets of pure quartz. There are also masses of quartz segregated in the midst of the granitic rock, with no intermediate pegmatitic stages.

The principal minerals of the rock are quartz, feldspar and muscovite. These are present in all relative proportions, the variation in mineralogy being especially marked in the large knob which terminates the intrusion at the southwest end. The predominant type contains all three minerals, but in some places large masses are made up of quartz and feldspar only and in others of muscovite and quartz only. All of the rocks contain much quartz.

The intrusive mass may, therefore, be divided into four readily

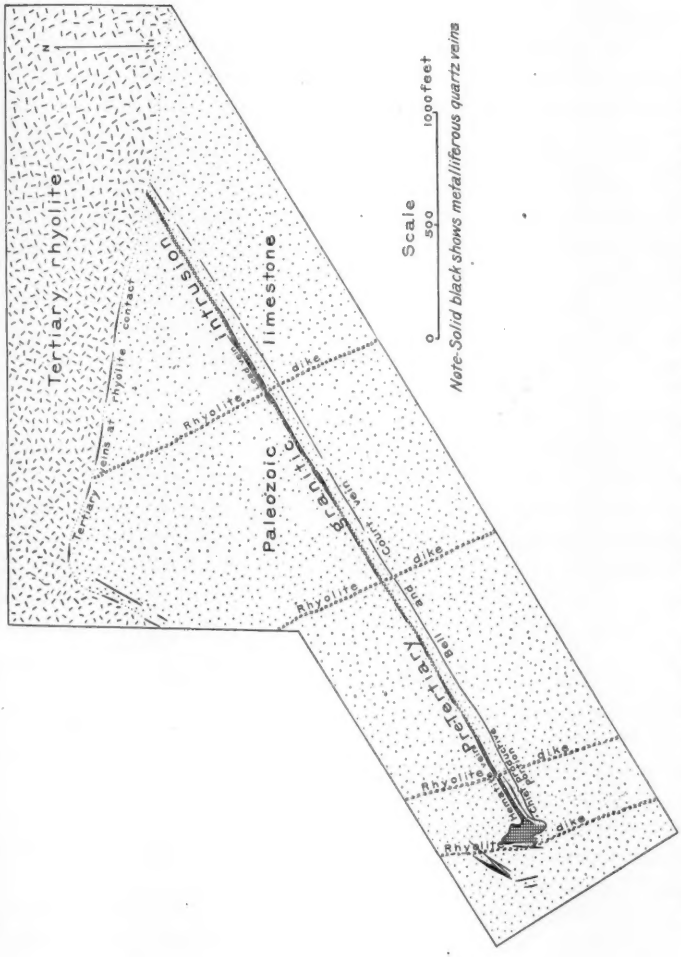

FIG. 30. Sketch map showing geologic conditions in the Southern Klondike district, Esmeralda Co., Nevada.

distinguished phases. Arranged in the order of their relative abundance these are:

1. Quartz-muscovite-feldspar rock (muscovite-granite).
2. Quartz-feldspar rock (alaskite).
3. Quartz-muscovite rock.
4. Quartz rock.

DETAILED DESCRIPTION OF ROCK TYPES.

1. *Quartz-muscovite-feldspar rock.*—From a study of numerous thin sections this rock is seen to vary greatly in the proportions of quartz, feldspar and muscovite which it contains, the muscovite, however, being always subordinate to the quartz and to the feldspar. Of the two last-named minerals, sometimes the one and sometimes the other is in excess. The species of feldspar include orthoclase, microcline and albite or oligoclase-albite. All varieties are usually fresh and unaltered, although kaolinization due to weathering is to be occasionally observed.

The muscovite is partly coarse and partly fine. In some thin sections it is all coarse, like the typical muscovite of granite; in others a large proportion is fine-grained and approaches in appearance the fine-grained variety of muscovite which is called sericite and which is often derived from the alteration of feldspar. In this rock, indeed, the feldspar is frequently intergrown with fine, small blades of muscovite and in such cases the latter mineral might be taken on casual examination to be a secondary product. Since the feldspar is fresh, however, the muscovite is undoubtedly contemporaneous with it.

The quartz encloses crystals of feldspar and muscovite and seems to have been the last mineral to crystallize.

There are no dark ferromagnesian minerals present. Accessory minerals include greenish-white garnet and small crystals of hematite, which are pseudomorphous after probable primary pyrite.

2. *Quartz-feldspar rock.*—The quartz-feldspar rock is connected by transitional stages with the quartz-feldspar-muscovite rock and like that rock it has an allotriomorphic granular structure and generally a medium fine texture. The essential miner-

als, quartz and feldspar, are present in varying proportions. The feldspar includes the species orthoclase, microcline and albite, and is sometimes turbid from kaolinization. It is occasionally slightly altered along cracks to fine muscovite (sericite), as a result, probably, of weathering processes. This secondary muscovite is to be carefully distinguished from the ordinary original muscovite of these rocks.

Accessory minerals include apatite, colorless garnet and titanite.

3. *Quartz-muscovite rock.*—The quartz-muscovite rock is connected by transitional phases with the two types above described. It is characterized by an allotriomorphic granular structure with a texture varying from medium coarse to medium fine. Typically it contains no feldspar whatever. The proportions of the essential minerals, quartz and muscovite, are variable, sometimes one and sometimes the other being predominant.

The muscovite is of two kinds, one coarse and one fine. There is often a transition between the coarse and the fine, but in general the two sizes belong to distinct classes, and illustrate different conditions of consolidation. Frequently most of a given thin section is made up of coarse intercrystallized quartz and muscovite, with typical granitic texture. This muscovite is primary, and is usually intergrown with the quartz, with which it is contemporaneous. In some cases large flakes of muscovite (often with a radial arrangement) are earlier than the quartz. The fine-grained muscovite is also intergrown and contemporaneous with fine-grained quartz, and this intergrowth frequently forms a second generation, later than the coarse quartz and muscovite. In certain sections the coarse muscovite may predominate, in others the fine. Both varieties seem plainly original. In some cases small matted areas of muscovite and quartz suggest, as a possible hypothesis, that these minerals have formed by the alteration of original feldspars. Nevertheless there is no question but that the coarse and the fine muscovite are of similar and nearly contemporaneous formation, as shown by frequent transitions from one to the other; and if the finer muscovite has in places resulted from the alteration of feldspar, the recrystallization must have

taken place during the rock's consolidation. This change, if there was such, was also probably effected before the consolidation of the quartz, for the quartz encloses not only the coarse muscovite, but in many cases the fine fibres.

Accessory minerals in the quartz-muscovite rocks include pseudomorphs of hematite after pyrite, and occasional small garnets.

4. *Quartz rock.*—Quartz "veins," which are a phase of the intrusive magma, arise by diminution and withdrawal of the feldspar and muscovite. Thin sections of these quartz veins usually show the presence of a small and variable amount of muscovite.

Accessory minerals include hematite and pyrite. In some localities these iron minerals have bunched together in the quartz, so that they make up what often appears to the naked eye to be a mass of pure iron ore. Near the surface the pyrite has altered entirely to hematite and limonite. Thin sections show that in the interstices between the separate hematite crystals there is granular quartz, which has solidified subsequent to the metallic minerals. Fine muscovite is also present.

CHEMICAL CHARACTERS.[1]

Following are analyses of the different types of rocks described above:

TABLE I.

1. *Quartz-feldspar-muscovite rock (Muscovite Granite).*

	Spec. No. 108.	No. 86.
SiO_2	71.80	75.64
Na_2O	3.50	4.22
K_2O	5.20	3.64

TABLE II.

2. *Quartz-feldspar rock (Alaskite).*

	No. 92.
SiO_2	70.32
Na_2O	2.65
K_2O	7.90

METALLIFEROUS VEINS.

Close to the contact of the intrusive granitic mass with the limestone, and following the contact on the southeast side for the whole length of the intrusion, is a quartz vein (see map, Fig. 30) which, near the surface, carries sporadic high values in gold and

[1] Of the accompanying analyses, Nos. 87 and 88 were made by Dr. W. F. Hillebrand, and the others by Dr. E. T. Allen, of the U. S. Geological Survey.

TABLE III.

3 and 4. *Quartz-muscovite Rock. Series Transitional into Quartz Veins.*

	No. 87.[1]		No. 97.	No. 91.	No. 88	No 116.	No. 90.	No. 96.	No. 99.	No. 117.
	a	b								
SiO_2	71.38	72.69	73.64	74.08	75.51	76.39	79.40	84.58	94.34	96.82
Al_2O_3	14.31[2]	13.42[2]			14.28[3]					
Fe_2O_3	.66	.97			1.09					
FeO	.28	.32			.38					
MgO	.25	.26			.28					
CaO	2.22	1.97			.34					
Na_2O	.15	.21	.54	.92	.20	.52	.82	.45	.21	.22
K_2O	3.79	3.36	4.84	4.65	4.69	3.98	3.68	2.87	.16	.17
H_2O—	1.60	2.36								
H_2O+	3.03	2.60			3.36[4]					
TiO_2	a little	a little			a little					
CO_2	1.42	.97								
P_2O_5	a little	a little			a little					
SO_3	none	none								
Cl		trace			trace					
F	.17	.25			.20					
S	none	none								
MnO	a little	a little			trace					
Li_2O					trace					
	99.26	99.38			100.33					
Less O=Fe	.07	.10			.08					
	99.19	99.28			100.25					

silver. Its average distance from the intrusive contact is 75 feet, the maximum about 100. This vein is called, from its discoverers, the Bell and Court vein. Its chief productive portion is near the southwest or knobbed end of the dike. The values are mostly silver (chiefly in the form of chloride), with some gold. Gold is relatively more abundant a short distance below the surface than at the surface itself. The most superficial zone, marked by considerable lead carbonate, extends from about 20 or 30 feet below the surface to 50 or 60 feet. Some of these ores are rich in both gold and silver, assaying up to 200 to 300 oz. silver, and $60 or $70 gold, or even higher. Occasionally a black-gray sulphide occurs, whose oxidation has resulted in some copper carbonate. This resembles the compound known as *stetefeldtite,*

[1] This analysis indicates the presence of a considerable amount of calcite (probably infiltrated) not revealed by the thin section.

[2] Incl. a little TiO_2 and P_2O_5.

[3] With a little TiO_2 and P_2O_5.

[4] By ignition.

which is a copper-antimony-silver compound, containing generally also gold. Such specimens are said to assay as high as 4,000 oz. to the ton. Some portions of the vein contain bunches of galena, a mineral from which the lead carbonate is probably derived by oxidation. Pyrite, some of it slightly cupriferous, is frequent. Among other minerals of the vein are siderite, calcite and hematite, and in one place a streak rich in wad (manganese oxide) was found. All these minerals, however, are in the petrographic sense accessory, the vein being almost entirely quartz.

From workings near the surface about $33,000 worth of ore has been shipped, consisting of 100 tons, averaging over $300 a ton; but the average tenor of the vein is exceedingly low, running from 2 or 3 oz. down to ½ oz. of silver.

The vein cuts at a small angle across the stratification of the sedimentary rocks, and is essentially a silicified shear zone. It follows the irregular curves of the knob-like mass at the south end of the alaskite intrusion so faithfully as to show a definite genetic connection with the dike. Plainly the shear zone was caused by the disturbance produced by the intrusion.

The quartz of the vein is partly white granular vein-quartz, partly jasperoid. It frequently contains numerous liquid inclusions, which enclose gas bubbles.

The vein described above is the only one that has been productive of commercial ore. There are, however, other vein formations. Parallel to the productive portion of the Bell and Court vein and between it and the intrusive contact, is a vein of jasperoid and quartz, carrying values up to $1 and $2 per ton (chiefly silver, with some gold). This jasperoid vein, representing, like the Bell and Court vein, a silicified shear zone parallel to the contact, appears to run into the Bell and Court vein on the south and there unite with it. Other veins of jasperoid or white quartz, or both, less persistent than those above mentioned, occur near the contact, in the intruded limestone. They mostly follow the stratification of the limestone, which is nearly parallel to the strike of the dike, but sometimes are diagonal to the formation. They are often iron-stained, and contain a little silver and gold. Under the microscope they show interlocking grains of quartz containing small crystals of magnetite.

Half a mile northeast of the productive portion of the Bell and Court mine, but close alongside a barren portion of the same vein, the writer studied a segregation of quartz within the granitic (alaskite) dike. At this locality crystals of galena and pyrite occur both in the quartz and in the adjacent extremely siliceous alaskite. Under the microscope the galena is seen to be contemporaneous with the quartz, and the quartz also encloses a very little accessory contemporaneous muscovite.

In places at the very contact of the intrusive rock with the limestone, especially near the knob which terminates the intrusion on the southwest side, there is a deposit of hard, nearly solid, hematite which reaches a maximum of 10 or 15 feet in thickness. This hematite has been shown to be largely derived from the oxidation of original pyrite, which was formed along the intrusive contact, in the granite and probably also in the limestone. These masses often contain pure quartz in considerable quantity, similar in appearance to that of the Bell and Court vein, and mixed with the hematite in all proportions. By a diminution of the hematite, phases arise which consist of quartz carrying disseminated oxidized pyrite, and by further diminution of the iron a nearly pure quartz originates. These different phases may be found along the same contact, and practically along the same vein. Such pyrite-bearing quartz veins follow the contact closely and occur especially in the granite (at the contact). In most localities, instead of a single vein, there is a band of large and small vein-like quartz masses, which are identical in nature with the segregated quartz bodies found elsewhere in the granite. These pyrite- or hematite-bearing veins sometimes occur on one margin of the dike, sometimes on both, and again are entirely wanting. This irregularity is characteristic also in a vertical sense, for in one place where workings have been sunk on a deposit of hematite for 30 or 40 feet, it has been found to decrease to almost nothing. The hematite is said to carry small amounts of gold, silver and lead, the average value being perhaps $2 to the ton. None of it has been mined.

About one-half a mile northeast of the knobbed end of the granitic intrusion, there is, on the northwest side of the dike, a

quartz vein similar, in nature and location, to the hematite-bearing veins, but containing considerable galena instead of oxidized pyrite. This "lead vein" may be traced continuously 200 or 300 yards, but is usually barren. It wedges out in the limestone in such a way as to indicate that it fills an opening caused by the granitic intrusion.

Mineralization Connected with the Tertiary Rhyolite.—Rhyolite forms several thin southwest-striking dikes, which trend at right angles to the alaskite dike and are intrusive into the limestone, the alaskite, and the veins associated with the alaskite. The veins, alaskite and limestone, are cut off by a large mass of similar rhyolite on the northeast. This rock contains phenocrysts of quartz and orthoclase, in a glassy ground-mass. Biotite is scarce and is usually altered.

Some silicification and ore deposition has accompanied the rhyolite intrusion. In one locality, where a small rhyolite dike has cut across the Bell and Court vein, the ore was very rich for 3 inches away from the intrusive contact, beyond which it was barren. This indicates either subsequent mineralization (later than the original ore deposition), or concentration of preëxisting values by the solutions attendant upon the rhyolitic intrusion. More definite proofs of mineralization mark the contact of the main rhyolite mass, which is intrusive, and trends irregularly but in a generally different direction from that of the alaskitic intrusion. The contact of the rhyolite and the intruded limestone is marked by irregular large reefs of iron-stained quartz and jasperoid, of a nature very similar to that which characterizes the contact of the granitic intrusion. The reefs contain some gold and silver, and have been prospected but not mined. This Tertiary mineralization is not believed to have any immediate genetic connection with the pre-Tertiary mineralization which is the main subject of this paper.

GENERAL CONCLUSIONS.

NATURE AND ORIGIN OF THE VARIATIONS OF THE GRANITIC ROCK.

Character of the Magma.—The granitic magma, intrusive in this locality, was siliceous and alkaline, varying considerably in

the proportion of soda to potash and in the amount of silica, as is shown by the analyses from the different portions. This considerable range of composition in different parts of alkaline (alaskitic) intrusions has been observed in other places, as for example, by the writer at Silver Peak,[1] in Nevada, and seems to be characteristic of this class of rocks. It also conforms with what is known as to the irregular segregation of elements in pegmatitic rocks, which are closely related to alaskites. In both cases the segregation may be explained by the assumption of relatively slight viscosity of the magma, which property has permitted strong currents to bring about the migration and massing of like materials. This assumption is warranted by other considerations which cannot be repeated here, but which show that siliceous magmas are in a relatively aqueous and fluid condition.

Relation of Rock Types.—The typical minerals of the Southern Klondike intrusive rock are quartz, feldspar, and muscovite. The feldspar is alkaline, the chief species being orthoclase and albite. When all three minerals are present the rock is a type which has been called muscovite-granite. Frequently, however, muscovite is rare or wanting, when the rock becomes an alaskite. Again, feldspar may be wanting, the result being quartz-muscovite rock, and finally, both muscovite and feldspar may be wanting, when quartz rock results. The typical method of transition into quartz rocks in this district is by diminution of the muscovite, which is analogous to the transition of alaskite into quartz rock by the diminution of feldspar, a change which has been observed in various districts, as at Silver Peak. Indeed, in all the phases of the Southern Klondike intrusion, an intimate relation between the muscovite and the feldspar (orthoclase) has been noted.

Origin of Muscovite.—In all the rocks there is some evidence of two generations of crystallization, the first having resulted in coarser crystals, the second in relatively fine ones. A given rock may be made up mostly of one generation or of the other, or both. The muscovite, like the quartz, occurs in these two generations. The coarse variety of muscovite is like that

[1] The Silver Peak geology is to be made the subject of a professional paper by the writer (published by the U. S. Geol. Surv.).

variety often called sericite. But the transitions between the two varieties are convincing as to their common origin. In the muscovite granite and in the alaskite, blades of the fine muscovite in feldspar frequently suggest a secondary origin; but in such cases it is probably essentially primary, since similar blades are also enclosed in the quartz of the same thin sections. The fine muscovite in feldspar therefore represents either earlier-crystallized fibres enclosed in later feldspar or the partial alteration of the feldspar to muscovite, before the final consolidation of the rock. That at least part of the fine included muscovite is actually secondary to the feldspar is shown by its distribution in zones parallel with the cleavages and with the margins of the crystals. In the quartz-muscovite rocks there are also often areas of fine muscovite and quartz, which are surmised to be due to the total alteration of original feldspars, but this fine muscovite is transitional in the same thin sections into the coarse muscovite typical of granites, and all have evidently been formed by the same processes.

The analyses of the quartz-muscovite rocks show that they have a chemical composition like that of many quartz-orthoclase rocks or alaskites, the place of the orthoclase of these rocks being typical of granites, and the finer grained phase resembles the taken by muscovite and quartz and having together practically the same chemical composition as the orthoclase.

The conclusion arrived at is that orthoclase has been attacked during consolidation, and partially altered to muscovite of varying degrees of coarseness. There is no reason to separate this secondary muscovite in nature and origin from true granitic muscovite.

The crystallizing agent was probably fluorine in the residual magma, for fluorine has been found to be necessary to the artificial production of mica,[1] and the analyses given above show the presence of fluorine in these rocks, undoubtedly contained in the muscovite. Analyses of muscovites from other districts typically show the presence of fluorine. The coarser muscovite of the rocks may also have been crystallized by the action of fluorine

[1] Doelter, "Chemische Mineralogie," p. 161.

upon the orthoclase molecule in the magma. This supposition concurs with the suggestion of Bischof.[1]

According to this explanation, the orthoclase molecule in the original intrusive magma in this district has crystallized entirely as orthoclase where fluorine was scanty, and quartz-orthoclase rock or alaskite has resulted. In those portions of the intrusive mass where fluorine was abundant, the orthoclase molecule has crystallized entirely as muscovite, and the result is quartz-muscovite rock. Where, however, the albite molecule was present in the original magma, alaskite or muscovite granite has formed, since muscovite cannot be formed directly from the albite molecule, and the resulting rock in this case always contains feldspar. These conclusions connote the idea that muscovite-granite is a crystallization phase of an alaskite magma, and is to be classed with the alaskites rather than with the granites.

Relation to Other Districts.—The features of this district are analogous to those at Belmont, Nevada, about 70 miles north of the Southern Klondike. Here, as the writer has noted in a previous paper,[2] a granitic intrusion similar in nature to that at the Klondike has cut through Silurian limestone-slates and is attended by ore deposits. The Klondike rock is also like that long known in the Ural Mountains under the name of beresite, which, as the writer has pointed out, is likewise the equivalent of some of the rock of the Belmont intrusion. From the literature concerning the Russian beresite, and from the examination of specimens and thin sections, as well as the recollections of a personal visit, the writer believes that the nature and genesis of the Russian beresite is similar to that of the rock in these Nevada localities. More recently the writer has studied similar phenomena at Silver Peak, Nevada.

The rocks in all these localities are regarded as ultra-siliceous phases of granitic magmas having the chemical composition of alaskite. The presence of much water and mineralizers in the magma has permitted irregular segregation of the alkalies. Crystallization in the presence of a varying amount of fluorine has produced, from the quartz-orthoclase magma, either musco-

[1] "Chemische und Physikalische Geologie," Vol. 2, p. 744.

[2] *American Journal of Science*, Vol. X., Nov., 1900, p. 355.

vite granite, alaskite, or quartz-muscovite rock; and from the quartz-orthoclase-albite magma muscovite-granite or alaskite. Segregation of the quartz has produced quartz veins which are mineralogically transitional either from the alaskites or (in the presence of a considerable amount of fluorine at the time of their consolidation) from the chemical equivalents of the alaskites, the quartz-muscovite rocks.

The whole intrusive mass in the Klondike district then, as well as that at Belmont, is a beresite, like that in Russia, the name signifying the peculiar character of the rock as first described at Beresovsk. Chemically it is alaskite and mineralogically it is muscovite granite (more properly muscovite alaskite), alaskite, and quartz-muscovite rock. If a special name is necessary to denote the variety of granitic rocks, consisting essentially of quartz and muscovite, the name esmeraldite may be applied, derived from the name of the county in which the Klondike district lies.

The Origin of the Ores.—In all the above cases where these peculiar beresitic phenomena have been noted, ore deposits are genetically connected with the intrusions. The ore deposits appear to be due to the action of the same residual siliceous magmatic waters and gases which have played so important a part in the consolidation of the intrusive rock. These mineralizers have brought about concentration of metals, which were also residual from the principal and earlier-crystallized portion of the magma.

In the Klondike district, the pegmatitic quartz segregated in the midst of the granitic intrusion, indicates that the end product of crystallization was quartz, which was deposited by residual siliceous magmatic solutions. The more or less metalliferous veins of jasperoid and white quartz at and near the intrusive contact are part of the phenomena of the zone of contact metamorphism, and seem to be due also to the siliceous granitic solutions. The deposits of pyrite and hematite at the contact of the intrusive rock also represent a phase of the contact metamorphism, having probably been formed by residual solutions rising along the contact and depositing quartz, pyrite, and hematite, both in the granite and in the intruded limestone.

EDITORIAL

With the present number the monthly magazine formerly published under the name of *The American Geologist* will be incorporated with ECONOMIC GEOLOGY.

This consolidation was contemplated by the founders of the new journal before the appearance of the first issue, and constituted a part of the plan which had been adopted in advance of publication.

It is with no little pleasure that the editors now announce the completion of the arrangements, both because it gives to them an opportunity to express their keen appreciation of the cordial reception which has been extended to the journal by scientific and practical men, and because the agreement will insure to the journal a permanence which might not otherwise be gained without many years of successful publication.

In the early consideration which the founders gave to the many questions involved in the establishment of a new journalistic enterprise, it seemed to them beyond doubt that the magazine might best be made of service if built upon the structure of some already established scientific periodical devoted to geology. A slight change in the scope of the geologic questions treated and a limitation of articles and discussion to questions of applied geology would then serve to render clear the economic character and aim of the journal.

They further felt that to defer the consolidation of the two journals until the purpose and industrial character of the new venture had been thoroughly recognized would avert any possible misconception of the field to be covered.

The American Geologist was established in 1888 and has been published with but little alteration and without interruption for a period of eighteen years. It has carried on its editorial staff many of the ablest geologists in this country, and has rendered

a service to science whose extent can not but command a most cordial recognition.

At the time of its establishment there were no other geological journals published in the United States, and the necessity for a geological magazine was proportionately great. Moreover, the efforts of investigators in the early history of geology in America were chiefly directed to the study of purely scientific and structural problems and no evidence of the dominant industrial trend had yet become manifest in geological science.

These conditions have now changed. The appearance of the *Journal of Geology* devoted to the purely scientific phases of the subject, and now for some years the able contemporary of the *American Geologist,* has made the maintainance of two such magazines, however advantageous, at least unnecessary. Also the awakening of interest in ore deposits and kindred questions which has taken place in the study of geology on account of the rapid development of the industrial resources of the country has rendered desirable the limitation of at least one geological journal to questions of applied geology.

It is but fair to say that at no time in the history of its publication have the affairs of the *American Geologist* been in a more prosperous condition than at the present time. The desire, however, of the editor to engage in other pursuits has led him to welcome a relief from the task, which for many years he has so well performed.

The knowledge that the field of pure geology is still to be ably covered by a successful journal, and the ever deepening interest in applied geology should cause both scientific and practical men to view with little regret the merging of an older magazine devoted to general questions with one whose aim is to further our scientific knowledge of the industrial sides of geology, and which is now in the vigor of its youth.

In conclusion it may be said that it cannot but afford satisfaction to those who are interested in the success of ECONOMIC GEOLOGY to know that the final adjustment of the business affairs of the journal has now been brought to a satisfactory conclusion.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, South Bethlehem, Penna. The full name of the author should be attached to all communications.

WHAT IS A FISSURE VEIN?

Sir:—I take it that the object of the present discussion is not alone to ascertain what, from an abstract point of view, may be called a fissure vein, but also to come to some common understanding among ourselves, as economic geologists, as to how we should use this term.

From the first point of view, I can hardly expect to add much of value to what has been so ably set forth by the geologists who have preceded me, but, as the question as to what practice in the usage of the term would best be adopted by the economic geologist of the survey has been present in my mind for many years past in the course of preparing recommendations designed to bring about uniformity in writing on economic subjects, I venture to offer some suggestions on the second line.

I think it is a mistaken assumption that the general use of the term "true fissure vein" dates back to the early Saxon and Cornish miners. Cotta in his definition says: "Veins are the filling of fissures. Mineral veins are, therefore, fissures which contain ore." But he uses the term "fissure vein" (Spaltengang) only in the single instance quoted by Spurr. I have failed to find it elsewhere, either in his or other German works, nor do I remember of seeing it in old Cornish writings. Prime's translation of Cotta used only the term "true vein" as distinguished from "bedded vein," etc. The very general use of the term "true

fissure vein" originated, I take it, in Whitney's "Metallic Wealth of the United States" (pages 43, 49). He was there describing the manner of occurrence of the lead deposits of the Mississippi Valley, then new to science, and for one of the prominent types of those deposits he invented the term "gash vein," which he evidently considered to be different from the typical or true vein hitherto described in works on ore deposits. The gash vein was the filling of a joint or crack in the limestone, and did not extend in depth beyond a given bed or stratum; whereas, the true vein was, according to him, "an aggregation of mineral matter accompanied by metalliferous ores within a crevice or fissure which had its origin in some deep-seated cause and may be presumed to extend *for an indefinite depth downward.*" The words that I have italicized evidently appeal to the American miner. His ideas are large and to be good his deposit must be inexhaustible or of indefinite extent. It was the fissure, according to Whitney, that was presumed to have indefinite extent; hence the miner coupled the word "fissure with that of "true vein" to denote the desired deposit of indefinite extent.

Dr. Raymond thinks it unwise to break the continuity of literature by unnecessarily killing a familiar term, but at the same time admits that it would be better to drop the term "fissure vein" altogether than to apply it to something that would never have been so called by the classic authors who invented that term. If I am right, however, this term, which combines the idea of the pre-existing open space and the material which has filled it, was not used by the classic authors and is of comparatively modern invention. It seems to me to constitute a popular fallacy whose perpetuation is highly undesirable, and my recommendation has, therefore, been to avoid its use as much as possible, and to especially avoid qualifying it by the adjective "true." Its use has, however, become so deeply rooted in the practice of the American miner that it would be impracticable to give it up entirely, but I should confine its use to such deposits as are manifestly what the classic authors, such as Cotta and his contemporaries conceive as ordinary or true vein deposits filling fissures. Some part of this fissure filling might be in the nature of replacement of mate-

rial previously included in the fissure, but if the fissure has been formed by the movement of one wall upon the other, there must necessarily have been some open spaces left to be filled.

I believe I was the first to insist on the fallacy of the old conception that all vein material is necessarily the filling of open spaces, but I did not go as far as to maintain, as Beck represents (2d ed., page 123), that metasomatic processes play the chief role in vein filling, nor do I now, though Messrs. Ries and Spurr seem inclined to take this ground.

If we attempt to use the term "fissure vein" in a genetic way, we run into such contradictions as calling the verticals of the Black Hills "fissure vein deposits," where the fissures themselves contain no ore. They are undoubtedly the channels through which the solutions rose that, spreading out in the calcareous beds of the Cambrian, formed the important gold deposits of that horizon.

However desirable it may be to have a genetic classification, it does not seem to me practical to give up form distinctions entirely. Dr. Raymond's paraphrase of Thackeray that "as for classification every gentleman has his own" contains a great deal of truth, for probably no working geologist will find that any of those proposed by others will exactly fit his own practice; still the underlying principle may be admitted that a sound classification should be primarily genetic, and yet in its subdivisions recognize the variance of forms. It should endeavor, however, to avoid the confounding in one term the filling with the space that is filled, as is done in the term "fissure vein."

S. F. Emmons.

UNIVERSITY TRAINING OF ENGINEERS IN ECONOMIC GEOLOGY.

Sir:—My remarks on this subject will be based upon a consideration of some of the ordinary requirements of the calling of a mining engineer. Confining attention to one whose practice involves the examination of mineral properties, it may be said that he is expected, from a comparatively brief inspection, to

pronounce upon the extent, value, and richness of an ore deposit; if it is cut off by a fault, to relocate it; if it pinches out or becomes lean and barren, to advise an abandonment or continuation and, if continued, direct the manner of procedure.

Now, upon an opinion rendered on these subjects lies great responsibility. A field geologist, working in "pure science," may commit a grave error in not locating a fault or recognizing its true nature when located; may fail to correctly correlate his results and, indeed, be guilty of a dozen other of the sins of omission and commission to which geologists are liable, and no further harm result than a temporary delay of the onward march of knowledge and a subsequent damage to reputation, when one better equipped with powers of observation shall go over the field. But the economic geologist suffers likewise in reputation and has the additional misfortune of bearing the blame for the loss of thousands and perhaps hundreds of thousands of dollars.

The economic engineer, then, although a specialist, is not necessarily narrow. Indeed, the profession calls for men of the broadest training, but who will apply that training along certain definite and narrow lines. He should, in order to deal successfully with the problems which he is sure to meet, be fairly well grounded in chemistry and petrology, know something of paleontology and much of stratigraphy and dynamic geology. He should be able to work out, if necessary, the entire structural geology of a region and the dynamics involved in its production; he must be able to satisfy himself as to the kind of a deposit with which he has to deal; whether fissure or segregation vein, shear zone, impregnation or replacement; whether due to deep-seated or superficial agencies. Not only must he do all these, but he must be sufficiently sure of his ground to make up his mind promptly and inspire confidence in his employers. Experience will count for much, but no amount of experience can, in the vast majority of cases, take the place of a thorough training in the rudiments of the science.

A student, then, proposing to follow the calling of a practical or economic geologist (I like the first name better) should, before beginning specialization, be well grounded in mineralogy, chem-

istry, and stratigraphic geology. These subjects, under favorable circumstances, he may be able to cover in his undergraduate course. His petrology, paleontology, deeper researches into dynamic geology, chemistry, including theory of ore deposits, and studies on the nature of the ores themselves, their mode of occurrence, and methods of extraction, must come later. And in this work the student should not merely make actual inspection of mines, but he should have access to large and varied collections of ores and minerals, not only of the nature seen behind the glazed doors of exhibition cases (and rarely elsewhere), but of the common type, loaded down with all manner of foreign materials and impurities, stained by iron oxides, and obscured by decomposition products. These he should handle and study, and thoroughly familiarize himself with all probable forms and associations.

A teacher, to be successful in this line, should be no mere lecturer, and the student should be taught not so much how to do things—perform certain stereotyped experiments—as to ground himself in such of the fundamental principles of the subject as shall enable him to think out and work out his own methods. And here it may be added that, when it comes to original thinking, there is no man so dangerous as he who is half taught, since he does not realize his own limitations nor comprehend all possibilities. The best work of any teacher is done by arousing interest and enthusiasm rather than by dogmatically laying down the law and nothing so brings a subject home to a student, makes it seem so real to him, as the introduction by his instructor of the results of his own experiences and researches. It is for this reason that an enthusiastic original investigator, although his method of presentation may be clumsy and obscure, will often turn out more students in his own calling than one who presents the subject more logically and connectedly but as dead as the Greek language and found only in the books. Bring to the student all the *ifs, ands* and *buts,* all the doubts and improbabilities relating to any subject, and then point out that solution which seems, with the information at hand, the most plausible.

The writer, as may readily be imagined from what has here

been said, is not one of those who believes in the shortening of college and university courses. Regretable though it may be, discouraging though it may be to students of slender means, the age is each day calling for men with broader as well as more highly specialized training. But there is serious danger that this specialization may begin too soon and particularly so with reference to the calling under discussion. There is, or should be, a wide difference between so training a student that he may apply his knowledge to practical problems, and merely training him for special work. The writer, not long since, in criticising a course of study prepared for one of the engineering schools, remarked that a student taking such a course was not acquiring an education, but simply learning a trade. The whole tendency was but to enable the student to do certain things in that particular branch of engineering. The fact that science is steadily and rapidly advancing seemed quite overlooked. The mining geologist, engineer, or by whatever name he may be called, as graduated from our universities, must possess not merely the knowledge necessary to enable him to perform the acts of his calling to-day, but to keep abreast with its progress also. As well might the builder of a modern sky-scraper contend that, because he must build high in the air, he has neither time nor means to go deep with his foundation, as a student, that, because of competition and the specific demands of his calling, he must begin at once upon the study of his special topic. One thus trained may for a time thrive and prosper, but he will some time meet with problems with which he cannot successfully contend and find, all too soon, that he has built higher than is safe with his meager foundation, and that further advance is impossible without inviting disaster.

The location of a university with reference to teaching economic geology undoubtedly may have much to do with the kind and thoroughness of the instruction given. Some are favorably situated with reference to iron mines, some to lead and zinc, some, again, to the precious metals; none equally so with reference to all. The cheapness of railroad transportation, particularly excursion rates, will, however, partially provide a means of overcoming nature's scattering of her resources, and visits of inspec-

tion to working mines should be made a part of every school's curriculum. At least two of our universities have of late adopted a summer school plan, in which classes spend several weeks in the field, making detailed studies of this nature.

Geology is not reckoned as an exact science. Yet the mining geologist is expected to make it sufficiently exact to warrant the investment of thousands of dollars. He, of all geologists, needs the most comprehensive training.

GEORGE P. MERRILL.

STRUCTURAL RELATIONS OF THE WISCONSIN ZINC AND LEAD DEPOSITS.

Sir:—The interesting and instructive paper by Professor Grant in the preceding issue of this magazine on the above subject accords with one of the structural relations in which zinc ores occur in northern Arkansas. Dr. J. C. Branner, ex-state geologist of Arkansas, has already called attention to what he considered a tendency of the ores of the region to collect in synclines,[1] but it was not his intention for the statement to be taken for any more than a suggestion to future workers in the field. Taking advantage of this suggestion as a guide to observation, the present writer, after a good deal of field experience in the region named, has become convinced that the synclines are favorable places for ore accumulation.

The rocks in which the zinc usually occurs, like those in the Wisconsin region, are of Ordovician age, and consist of magnesian limestone containing a good deal of chert in nodules, and a few thin beds of sandstone. They also contain a small amount of shale, but in no place observed by the writer is ore associated with or near it. For the most part they are horizontal.

When out of the reach of atmospheric agencies, the ore is the sulphide, whether above or below the groundwater level, except in the cases in which it is closely associated with sandstone, when it is a silicate (calamine). The sulphides of iron and lead but rarely occur associated with the zinc. Dolomite is the most com-

[1] Geol. Surv. of Ark., Vol. V., 1892, p. 32.

monly associated mineral. Most of the profitable ore occurs in joints, which were formed presumably at the time of folding, though some of it is disseminated. The disseminated ore is quite generally distributed through the Ordovician rocks of the region at certain horizons, but only in synclines or other structural features has it collected in such quantities as to attract the prospector. Everything points to these rocks being the source of the ore, which has been leached out by the circulating underground water and concentrated along favorable places for movement, of which the syncline is one.

Other favorable places for ore accumulation in the Arkansas field are faults, and the crests of small anticlines in which the most brittle beds are much broken, apparently from rather rapid folding of the rocks. In the latter case, the broken beds are cemented into coarse breccias by dolomite which in places carries more or less sulphide of zinc.

A. H. PURDUE.

REVIEWS

The Nature of Ore Deposits. By Dr. Richard Beck, Professor of Geology and Economic Geology in the Freiberg Mining Academy. Translated and revised by Walter Harvey Weed, E.M., geologist, United States Geological Survey, with two hundred and seventy-two figures and a map. First edition in two volumes, New York and London *Engineering and Mining Journal,* 1905.

The first edition of Dr. Beck's "Lehre von den Erzlagerstätten" was published in Berlin in 1901, and was followed by a second edition two years later, in 1903. Simultaneously with this second edition a French translation of the work appeared. The English translation by Mr. Weed, which has just been issued, may be considered as the third edition of the work.

Mr. Weed states in the preface that he was originally asked by the publishers to practically re-write the book from an American standpoint, giving greater prominence to American ore deposits, but that this idea was abandoned because it would involve serious abridgments of the descriptions of important foreign localities, which descriptions make the work especially valuable to American engineers and geologists. Mr. Weed has not, however, confined himself solely to translating the work, but has written new descriptions of many American ore deposits which have, of recent years, been carefully studied. The nomenclature employed in the German edition has in some few details been made to conform more closely to American usage, but otherwise the book is essentially identical with the last or second German edition with the exception of Mr. Weed's additions. In this English edition, however, the book appears in a form which is more conveniently handled; the single large volume of the German edition having been divided into two volumes. This division

has, however, been made, strangely enough, in the middle of a section without reference to the sense of the text, while by adding a few more pages to the first volume a much more suitable division of the subject matter could have been obtained. The book is clearly and simply written, and is well illustrated by cuts and diagrams. It is the most comprehensive general treatise on the subject of ore deposits which we now have in the English language.

After a preliminary section dealing with definitions and literature, the Classification of Ore Deposits is taken up.

The classification adopted is as follows:

(I.) *Primary Ore Deposits.*

A. Syngenetic; formed simultaneously with the country rock.

1. Magmatic segregations.
2. Sedimentary ores.

B. Epigenetic; formed later than the country rock.

1. Veins.
2. Epigenetic deposits other than veins.

(*a*) Epigenetic deposits; formed essentially by an impregnation of non-calcareous rocks, the deposits being generally in distinct beds.

(*b*) Epigenetic stocks; formed essentially by a metasomatic replacement of calcareous rock mostly in the form of stocks, pockets or stringers.

(*c*) Contact metamorphic ore deposits; ore beds and stocks formed through contact metamorphism caused by Plutonic intrusive masses.

(*d*) Ore bearing cavity fillings; deposits formed essentially by a simple filling of pre-existing cavities mostly in the form of stocks or stringers.

(II.) *Secondary Deposits.*

1. Residual deposits.
2. Placer deposits.

Each of the classes of ore deposits is then considered in succession, and some of the most notable examples described.

Under the head of Magmatic Segregations three classes are distinguished, namely:

1. Segregations of native metals.
2. Segregations of oxide ores.
3. Segregations of sulphide and arsenical ores.

With regard to group three it is stated "that the evidence that deposits of this class are direct segregations from a molten magma is not as clear and conclusive as it is in the case of groups one and two." This, it is affirmed, is particularly true of the Norwegian nickeliferous pyrrhotites and it is added that recent microscopic study has proved that the Sudbury deposits are metasomatic replacements and that there is "not a single example of magmatic copper deposits known in North America." Whether this conclusion is justified or not the readers of ECONOMIC GEOLOGY will, it is hoped, have an opportunity of judging for themselves after reading a series of papers on these Sudbury deposits, which will appear shortly in this magazine, by several gentlemen who have devoted special study to these deposits and who are in a position to speak authoritatively concerning them.

The Bedded Ore Deposits, which are next considered, are represented by a large number of occurrences, chiefly European, which are well described. Among the American deposits of this class are the ores of the iron ranges of Lake Superior. The treatment of these is rather inadequate, and it would seem better, even at the cost of slightly enlarging the book, to have presented a more complete and better balanced account of what are in fact the most important iron deposits in the world. In the account as given there are some inaccuracies. Thus, on page 78 the "soft ores" are said to be brown hematite. These ores, however, do not hold sufficient water to be so classed, for while undoubtedly specimens of brown hematite can be obtained from these soft ores, they, as a class, are essentially red hematite, only partially hydrated, the average content of water in the Marquette ores being about 5.4 per cent., while in the Mesabi Range, whose product may be said to consist entirely of soft ores, the average content of water is only 7 per cent., while brown hematite has twice this amount of water. Again, on page 23, the

iron ores of the Mesabi Range are said to belong to the class of magmatic segregations, while on page 80 they are said to have originated in the same manner as those of the Penokee-Gogebic and other iron ranges of the district, which are classed as sedimentary deposits. On page 78 grünerite is referred to as "almost pure *ferric* silicate in the form of hornblende." In the same class are the Clinton ores which also merit a much more extended description.

The Epigenetic Deposits are then taken up, their description being prefaced by an excellent "General Description of Mineral Veins," treating of their structural relation to the country rock, structure of the vein filling, etc., and including a discussion of the origin of vein fissures and of the dislocation of veins, faulting, etc., which occupies eighty pages.

The numerous occurrences of vein deposits are grouped according to the ore which they contain, and examples of the several groups are considered in succession. The definition of a vein given by Emmons, "A single mineralized fissure, or the ore body formed along a single fissure," is accepted, although Beck states that he "does not entirely agree with S. F. Emmons, who attributes the important rôle in the formation of many veins to metasomatic processes, as such processes are always regarded by him (R. B.) as subordinate phenomena in vein formation."

Under this class of deposits a good description is given of the tin deposits of the Erzgebirge, and it is noted that in the case of the Zinnwald occurrences at least "the impregnation with tinstone occurred before the last phase of volcanic activity in the region." This is followed by briefer descriptions of the Cornish tin deposits and of the "tin districts" outside of Europe.

The next section treats of that extremely interesting class of deposits which mark the transition between tin deposits of the usual type and ordinary mineral veins, and which find their best exemplification in the occurrences of the Cerro de Potosi and other Bolivian deposits. Under this heading are also described the veins of Butte, Montana; and the native copper deposits of Lake Superior are here taken up as a whole, although few of the important deposits of this region are really veins. This latter

very important district is also one which merits a more extended description, the conglomerate deposits being disposed of in some six lines. The opinion is expressed that "genetically these deposits are best explicable by the assumption of a lateral secretion of the copper ores which were originally finely distributed in the melaphyres, the only enigma being why the secretion and concentration took the form of native copper."

It is noted in the discussion of the silver lead veins that the three types of these veins recognized by Herder in the Freiberg district, have been found to exist with but little variety in the mineral districts of all parts of the globe, "so that they are really of universal application." These are: (1) The pyritic lead quartz veins, (2) the high grade galena veins with carbonated gangue, and (3) the galena barite veins. The veins of these classes in the Freiberg district are described in detail, and a good map, showing the distribution of the several systems of veins in this classical locality, is given. Representatives of the several classes in many other parts of the world are also described and compared with respective occurrences in the Freiberg district.

The veins of the rich cobalt silver ores of the Joachimsthal and Annaberg districts, to which the recently discovered veins of the Cobalt district of Ontario are so closely allied, are then described in detail. It is mentioned that as early as 1517 a mining settlement existed in the Joachimsthal district, and that in 1518 the first "Joachimsthaler" was minted, this coin now being known as the "Thaler." It is stated that special attention is now being paid in these districts to the extraction of uranium.

In connection with the gold quartz veins, their close relation to pegmatite intrusions is noted. During the cooling of a body of granite magma, the water and the various gaseous compounds became more and more concentrated in the residual mother liquor during the crystallization of the magma. The residual solutions, penetrating into fissures, deposited vein quartz together with vein substances and non-silicated compounds, which were comparatively uniformly distributed in the molten magma but which gradually retreated into the residual water.

Having described these deposits, an abrupt break is made, and

the "General Description of Veins" is resumed and continued through forty pages. The statement made to the effect that this description is continued from page 226 is evidently a misprint, as it is really continued from page 195. This section takes up the consideration of "Differences in Vein Content at Different Depths," which are considered under the heads of changes in primary filling and changes due to secondary alteration; "the Distribution of Ore within the Vein"; "the Influence of the Country Rock on the Richness of Lodes"; "the Influence of the Vein Intersections on Ore Content"; "the Influence of Converging and Diverging Stringers on the Content of Veins"; "Action of Vein Solutions upon the Wall Rock," etc.

Under the changes in the character of primary ore filling, the progressive replacement of galena by zinc blende and pyrite in depth is noted in the case of a number of well known occurrences, as, for instance, in the Freiberg veins, in those of the upper Harz, in the silver lead ores of the Castle Mountain and Barker districts of Montana, as well as in the Elkhorn deposits. This same change has also been observed in other cases not mentioned by the authors, as in the Joplin district of Missouri, which is mentioned by Van Hise, and in the silver lead veins of the Kootenay district of British Columbia. This change, however, in the case of the Missouri occurrences is regarded by Van Hise not as one of primary ore filling but as due to the secondary action set up by descending waters.

The superficial alteration of ore deposits in the zone of weathering and the various classes of products resulting from this are then described at length.

The "Action of the Vein Forming Solutions upon the Wall Rock" is taken up and considered under the heads of "Sericitization," "Kaolinization," "Propylitization," "Silicification," "Alteration of limestones into ore-bearing pyroxene-epidote rocks," "Tourmalinization" and "Topazitization" and "the Metasomatic replacement of the country rock by Ore."

There is inserted at this point a "Review of the various Theories of the origin of Mineral Veins." These are classified as follows:

1. Congeneration Theory.
2. Descension Theory.
3. Lateral Secretion Theory.
4. Ascension Theories:
   (*a*) The Igneous Injection Theory.
   (*b*) The Sublimation Theory.
   (*c*) The Hydrothermal Theory.

Numbers 1 and 2 may now be said to be of merely historical interest and with regard to the theory of Lateral Secretion, the opinion is expressed "that any general application of the theory is decidedly impracticable," although a few occurrences are mentioned which may have originated in this way. The Igneous Injection Theory is also of merely historic interest although it has lately been resuscitated by Weinschenk and applied to the pyrite deposit of Bodenmais. The authors maintain that the Hydrothermal Theory affords the true explanation of the origin of mineral veins. "We maintain that the original formation of most ore bodies is due to *thermal water rising from great depths. These thermal waters are believed to be the after-effects of Plutonic eruptions, such as the intrusion of granitic masses;* also of volcanic events in the narrower sense." It is not clear, however, whether these thermal waters, which are the after-effect of volcanic action, are regarded by Beck as "juvenile" waters in the sense of Suess, or are waters which having percolated from the surface have been rendered especially active agents of solution and deposition by the heat communicated to them by the intrusions in question.

The description of "Epigenetic Ore Deposits in Stratified Rocks" is then taken up, and a large number of occurrences are described, among the more important of which is the Mansfield "Kupferschiefer" and the Transvaal gold-bearing conglomerates. With regard to the former, the authors do not believe that the copper was derived from any process of direct precipitation from the ocean waters in which its shale was laid down, but point out that "wherever the formations comprehended under the name Kuperschiefer are ore-bearing, the Zechstein and its underlying rocks are found traversed by numerous fissures which have in

part the character of mineral veins. The generally recognized fact that with few exceptions the amount of copper in the shale increases on approaching these fissures and dislocations is direct evidence in favor of impregnation from the fissures."

The Transvaal gold-bearing conglomerates are described in considerable detail, and the various theories which have been proposed to account for the gold in them are discussed, that which accounts for the subsequent introduction of the gold by the invasion of the porous conglomerates by gold-bearing solutions being preferred.

The term *epigenetic ore stock* is given to all stock-shaped, pocket-shaped and tube-shaped ore bodies found in limestone or dolomites, and which are formed by the metasomatic replacement of the carbonates by ores and accompanying minerals. Among the examples of these, the spathic iron ores of the Bilbao district, the copper deposits of Bisbee, Arizona, the ore deposits of Laurium, the lead and zinc deposits of the Mississippi Valley and others, are described. Beck considers that in the case of the last-mentioned "the presence of barite and fluorite, in fact the entire mineral assemblage of the deposits, so closely resembling that of the genuine silver-lead veins of hydrothermal origin, indicates that the hydrothermal theory is the correct one, especially since it will hardly be proved that the zinc and lead contents of the limestone were not themselves introduced by subsequent infiltration." A similar origin is attributed to the Leadville deposits.

The Contact Metamorphic Ore Deposits, to which an ever increasing number of ore deposits is being referred, embraces ore bodies formed within stratified rocks under the influence of contact metamorphism near or along the boundary between plutonic eruptive masses and stratified rocks. The most important criterion for the recognition of these deposits is considered to be their mineralogical composition, the ore being characterized by the presence of certain minerals which we know elsewhere to be typical of igneous contact zones—*e. g.*, garnet, wollastonite, vesuvianite, andalusite, cordierite, scapolite, etc. There is, as is

pointed out, a very close genetic relationship between ore bodies of this class and magmatic ore segregations.

The contact ore deposits of Banat, Hungary; those of the Christiania region and of the Island of Elba; with a number of others, are described as examples of this class of ore bodies, which is one that merits a much more close and thorough study than has heretofore been given to it.

The work closes with the consideration of the several classes of detrital deposits.

The book is an excellent one and is especially useful to the English-speaking student as presenting a description of many foreign ore deposits, information concerning which is otherwise to be found only by extended search through a great mass of literature. The book, however, might be improved if the material were in a measure re-arranged, by discussing for instance the origin of all the epigenetic deposits in one section instead of taking up the question of origin in connection with each subdivision separately, for the same reasoning applies to all these deposits irrespective of shape.

The type employed for the headings of the various sections might also be made more distinctive as in the German edition which, in this respect, is much clearer. There also seems to be some mistake with regard to the statement on the title page that the book is illustrated by 272 figures, as only 257 can be discovered by the reviewer. These, however, are minor faults, and the book is one which every one interested in this most important branch of gology will welcome.

FRANK D. ADAMS.

Loon Lake Iron-bearing District. By W. N. SMITH. Report of the Ontario Bureau of Mines, Vol. XIV., 1905. Pt. I., pp. 254–260.

The Loon Lake iron-bearing district on the northwest shore of Lake Superior, about twenty-five miles east of Port Arthur, is of interest in that it exhibits a productive eastern continuation of the Animikie or Mesabi iron-bearing series, in diagrammatic relations to Keweenawan, Lower Huronian, Keewatin and Laurentian rocks. An area of about one hundred and forty square miles, mapped by Smith and his assistants, probably presents

more clearly the essential features of Lake Superior pre-Cambrian geology than any other equivalent area in the Lake Superior region. The succession is as follows:

Pleistocene	Glacial drift.
Unconformity.	
Keweenawan (Nipigon)	Conglomerate, sandstone, marl, diabase sills.
Unconformity.	
Upper Huronian (Animikie)	Iron-bearing formation and black slates.
Unconformity.	
Lower Huronian	Graywacke, greenstone, granite.
Unconformity.	
Keewatin	Green schists, greenstone, mashed porphyries.

To this succession should be added Laurentian granite, lying just to the north of the district but not included in the mapping. Laurentian, Keewatin and Lower Huronian rocks form the older land to the north. Resting upon their southern slope, with pronounced unconformity, is the Upper Huronian Animikie or Mesabi series, dipping gently to the south, and overlying this in turn, with pronounced unconformity but with slight discordance in bedding, is the Keweenawan series. Faulting has complicated the areal distribution.

Four definite horizons are present in the Animikie iron-bearing series as follows: (1) A lower iron-bearing member; (2) an interbedded black slate; (3) an upper iron-bearing member, and (4) upper black slate. These horizons indicate a continuous period of deposition, during which the conditions varied between those of chemical and probably also organic sedimentation, producing the iron-bearing formations, and those of mechanical sedimentation, with the production of the slates. It is believed that the general processes and agencies which produced the iron-bearing formations in this area are analogous to those which produced the iron-bearing members of the ranges in Minnesota and Michigan. The upper of these two iron-bearing members gives evidence of derivation from iron carbonate, while the lower contains granules and phases similar to the ferruginous cherts or taconites of the Mesabi range, suggesting derivation from

greenalite (ferrous silicate) rocks. Here seems to be an area in which it may be possible to determine finally the genetic relations of the two original iron formation substances, iron carbonate and greenalite. To the west, in the Mesabi district, the greenalite has been the principal original rock of the iron formation, while to the south in the Gogebic district in the same series iron carbonate has been the principal original rock. Concentration into hematite has followed the bedding of the lower horizon, that nearest the underlying basement. As the thickness of this horizon is not great, fifty to sixty feet, the question of commercial bodies of ore depends largely on the horizontal element. The layers showing the greatest concentration contain a large amount of lean siliceous material, either as lenses in the hematite or as layers interbedded with it. In these layers, including the siliceous material, the content of metallic iron varies from 30 to 46 per cent., phosphorus .017 to .256. Ore is also found at or near fault planes, where again it is associated with lean siliceous cherts. Hand sorting will raise the grade.

C. K. LEITH.

Iron Ranges of Michipicoten West. By J. M. BELL. Report of the Ontario Bureau of Mines, Vol. XIV., 1905. Pt. I., pp. 278–355. With geological map.

This report covers the northern and western extensions of the producing Michipicoten iron district, adjacent to Michipicoten Bay. The northern range lies between the Magpie River and the western branch of the Pucaswa River, practically continuous with the old Michipicoten range. The western range, separated from the other by granite, lies between Otter Head and Bear River on the Lake Superior shore and extends but a short distance north of Lake Michi-Biju. Coleman and Willmot's report on the Michipicoten area in the vicinity of the Helen mine is followed closely. Their succession is:

Keweenawan	Basic eruptives.
Post-Huronian	Acid eruptives.
Upper Huronian	Doré formation.
Unconformity.	
Lower Huronian	1. Helen iron formation. 2. Michipicoten schists, etc.

Under the recommendation of the Joint Geological Committee, referred to in a footnote, the Lower Huronian schists and iron formation would be classed as Keewatin and the Doré formation of the Upper Huronian would be called Lower Huronian.

The Helen formation consists of sideritic and pyritous cherts, jaspers, amphibolitic schists, siderite, iron ores, quartzite, phyllites, biotitic and epidotic schists, all undoubtedly sedimentary. The formation occupies a position generally close to the overlying Doré conglomerate, but sometimes great masses of green schists (Keewatin) intervene between it and the Doré formation. Pronounced faults in the iron formation may be seen in several parts of the north and west Michipicoten ranges. The western range is less folded than the northern range. The origin and development of the different phases of the iron formation are thought by Dr. Bell to be those given by Van Hise for Lake Superior troughs, such as those at Iron Lake, Frances mine, Brotherton ores, and emphasis is laid on the similarity of conditions in the Michipicoten and Vermilion districts.

Glacial erosion seems to have removed the upper parts of the formations, and ore deposits should be looked for only in deep hill, at the Leach Lake bands in the northern range and in Laird's claims, Julia River bands, David Katossin claims and Lost Lake claims in the western range. No important ore deposits have yet been found.

C. K. Leith.

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COMPILED BY

F. H. MOFFIT AND D. W. OHERN.

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SCIENTIFIC NOTES AND NEWS.

PROFESSOR J. A. UDDEN, of Augustana College, returned during the holidays from the Rio Grande country in Texas, where during the last seven months he has been in charge of an economic survey of the lands belonging to the New York and Texas Land Company, Ltd.

THE STATE GEOLOGICAL COMMISSION of the State of Illinois, at its meeting at Springfield in January of the present year completed the organization of the corps of the survey and arranged for the season's work. The following appointments were made to the regular force, and in addition the director was authorized to make such temporary appointments as might be necessary, subject to confirmation at a succeeding meeting of the Commission.

Professor C. W. Rolfe, of the State University, consulting geologist in clay work.

Professor R. D. Salisbury, of the University of Chicago, consulting geologist in charge of educational work.

Dr. U. S. Grant, of Northwestern University, consulting geoloigst in lead and zinc work.

Professor S. W. Parr, of the State University, consulting chemist in coal work.

Dr. Edward Bartow, director State Water Survey, consulting chemist in water work.

Mr. F. B. Van Horn, recently of the Missouri Geological Survey, assistant geologist.

Mr. F. F. Grout, recently of the West Virginia Geological Survey, assistant chemist.

H. B. Fox, of the State University, assistant geologist.

J. A. Udden, Professor in Augustana College, geologist.

W. W. Atwood, of Chicago University, geologist.

Dr. Stuart Weller, of Chicago University, geologist.

Mr. Ross C. Purdy, of the State School of Ceramics, chemist.

Not all of the men appointed will be able to devote their full time to the survey work, but assurances have been received that all will devote some time to it. Professor Rolfe and Mr. Purdy, assisted by Mr. Fox, will devote particular attention to the clay resources of the state beginning their work probably with a study of paving brick and the clay used in its manufacture.

Professor Parr, Mr. Grout, Mr. Van Horn and the director of the Survey, Mr. Bain, will devote their time largely to a study of the coal fields. It is proposed to take samples of the various seams and to study their qualities as well as their distribution in the field. In the latter work Dr. Weller and Mr. Atwood will assist.

Professor Udden will devote his time to a study of the underground waters of the state with a view to the determination of the limits of the various artesian basins and the depth to which it is necessary to go to obtain good water for municipal and other purposes. In this work he will be assisted by Dr. Bartow and the State Water Survey which will make the necessary analyses and laboratory tests.

Dr. Grant, with such assistance as may be necessary, will take up the study of the lead and zinc fields found near Galena, continuing the work done by the state of Wisconsin.

Professor Salisbury, assisted by various others yet to be appointed, will prepare a series of bulletins for use in the schools, descriptive of the geography and the geology of important type localities within the state. So far arrangements have been made for such bulletins covering the lake shore from Evanston north, the Illinois Valley near Peoria, and the Mississippi Valley between Savanna and Rock Island, and at East St. Louis. The first of these bulletins is now being prepared by Mr. Goldthwaite, of Northwestern University, and Mr. Atwood, of Chicago.

THE TENTH SESSION of the International Geological Congress will be held in Mexico, beginning September 6, 1906. A circular has recently been issued by the Committee on Arrange-

ments which gives in considerable detail the ground which will be covered by the scientific papers there to be presented, and outlines the excursions in which it will be the privilege of those attending the Congress to participate. This Congress is of especial interest to the readers of ECONOMIC GEOLOGY inasmuch as many of the subjects which are to be discussed bear rather directly upon the genesis and character of ore deposits, and also because the clear understanding of the geological conditions of Mexico has become of great importance to those interested in mining in that country.

The circular is divided into four portions. The first contains a list of the excursions which will be held before the opening of the regular business session of the Congress on September 6; the second gives the excursions to be held during the progress of the Congress; the third the excursions given after the close of the Congress, and the fourth the character of papers that will be presented at the business session.

It is stated that the work of the regular session of the Congress will be divided into four parts, which will be arranged as below, the names which accompany the titles being those of geologists and engineers who have consented to participate in the discussion or to present papers upon the subjects to which their names are attached:

I. *The Conditions of Climate in the Several Geologic Epochs:* Messrs. G. Boehm, T. C. Chamberlain, W. B. Clark, W. H. Dall, W. M. Davis, A. Heilprin, V. Uhlig, S. W. Williston.

II. *The Relations Between Eruptive Rocks and Structure:* Messrs. A. Bergeat, A. Dannenberg, G. K. Gilbert, J. P. Iddings, A. Karpinski, A. Lacroix, Ed. Maumann.

III. *The Genesis of Metalliferous Deposits:* Messrs. B. von Inkey, F. Klockmann, W. Lindgren, W. B. Phillips, J. E. Spurr, W. H. Weed.

IV. *The Classification and Nomenclature of Rocks:* Messrs. W. Cross, J. P. Iddings, A. Karpinski, A. Lacroix, A. Osann, W. B. Phillips, H. S. Washington, F. Zirkel.

The following excursions have been arranged according to the grouping mentioned above:

I. Excursion for the purpose of observing marine fossiliferous rocks of Cretaceous and Tertiary, together with recent volcanics and structural features. Excursion is made by railroad from Mexico to Jalapa, from Jalapa to Vera Cruz, and from Vera Cruz to Orizaba; duration of excursion four days.

II. Excursion to the south of the City of Mexico for the purpose of studying the marine fossiliferous Cretaceous and the crystalline schists. This excursion will include the railroad journey from Tehuacan to Oaxaca, under the leadership of M. Ordoñez; a visit to the ruins of Mitla and the return to Oaxaca; from Oaxaca to Tehuacan; a visit to the Lacustrine Tertiary and lower Cretaceous measures around San Juan Raya under the leadership of M. Aguilera; and thence from Tehuacan by Puebla to Mexico. Duration of excursion eight days.

III. Excursion to the recent volcanic and geyser regions of Nevado de Toluca; to the volcano of San Andres, under the leadership of M. Waitz; to the volcano of Jorullo, under the leadership of M. Ordoñez. Time required fourteen days.

IV. Excursion to the geyser region of Ixtlán and the volcano of Colima, under the leadership of M. Waitz. Duration of excursion seven days.

The following excursions will be held during the session of the Congress:

I. Excursion to the silver mine region at Pachuca under the leadership of M. de Landero. Duration of excursion one day.

II. Excursion to the bad lands of San Angel under the leadership of M. Ordóñez. Duration of excursion one day.

III. Excursion to Apapasco,
IV. Excursion to Cuernavava, } the same day.

The following excursion will be held after the close of the Congress:

This excursion will last for twenty days and will be among the most comprehensive of those planned during the entire meeting of the Congress. To the north for the purpose of studying the Triassic, Jurassic, Marine fossiliferous Creta-

ceous and Eruptive rocks, the relation between structural and eruptive masses; the lead, silver and copper mines and the coal and petroleum deposits. The start will be made for Salamanca and the Valley of Santiago by railroad, and the following features will be observed: A crater in eruption, the silver mines and geology of Guanajuato, the upper fossiliferous marine Trias and silver mines at Zacatecas, the geology and lead and silver mines at Mapimí, the geology and sulphur mines at Conejos, the relations between the structural and eruptive rocks and the marine fossiliferous Cretaceous at Juarez, the general geology at Parral and the silver mines at the same place, the structure and upper fossiliferous Cretaceous at Parras, structural geology at Mazapil, the copper mines at Aranzazú, the upper Jurassic and lower fossiliferous Cretaceous at Santa Rosa, the coal mines in the upper Cretaceous at Las Esperanzas, structural features at Monterrey and the same at Tampico, and the petroleum region of Ebano.

In addition to these regular excursions Sir Weetman D. Pearson has courteously extended the opportunity (without charge) to the members of the Congress for a seven- or eight-day trip to the Isthmus of Tehuantepec. Duration of this trip will be seven or eight days and will be chiefly concerned with the observation and study of the marine Tertiary, structural features and crystalline schists.

The subscription for membership is $4.00, U. S. Currency; the special book recording the excursions will be furnished for $2.00, U. S. money. The general secretary of the local committee is Mr. Ezequiel Ordoñez, 5a del Cipres, No. 2728, Mexico, D. F.

MR. F. L. RANSOME, of the U. S. Geological Survey, who has been occupied with field work in Nevada, has recently returned to Washington for the winter.

THE NINETIETH MEETING of the American Institute of Mining Engineers was held in South Bethlehem, Pa., on the 21, 22, 23 and 24th of February, 1906. The business meeting of the Institute was held in quarters provided by Lehigh University, and a number of interesting papers were read.

At the conclusion of the regular meeting of the Institute a number of excursions were arranged for the members.

Excursions were held (1) to the works of the New Jersey Zinc Company at Palmerton, the works of the Atlas Portland Cement Company, of the Lehigh Portland Cement Company, and of the Thomas Iron Company, all of which companies had kindly extended invitations; (2) to the works of the Ingersoll-Rand Company, near Phillipsburg, New Jersey, and of the New Jersey Zinc Company at South Bethlehem.

MR. WALDEMAR LINDGREN, of the U. S. Geological Survey, has returned from Paris and is now in Washington, D. C.